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Contents

PAGE 73 THE INTERNATIONAL GEOPHYSICAL YEAR

74 HIGH-CAPACITY ALTERNATORS FOR POWER STATIONS
by W. J. CARFRAE, B.SC.(ENG.), MEMBER

81 ELECTRICAL SCIENCE AND THE ELECTRICAL INDUSTRY
by PROFESSOR G. H. RAWCLIFFE, M.A., D.SC., MEMBER

86 FROST PREVENTION IN CONCRETE BY ELECTRICAL MEANS
by C. B. COX, ASSOCIATE MEMBER

88 ARC INTERRUPTION—PART 2
by H. EDELS, B.SC.TECH., PH.D., ASSOCIATE MEMBER *and* F. W. CRAWFORD, B.SC.(ENG.), PH.D.

94 A REVIEW OF THE *PROCEEDINGS*, PARTS A AND B

106 FRESH EMPHASIS ON VARIETY REDUCTION IN INDUSTRY

108 ARS MARTIS COMES

109 CORRESPONDENCE

111 OBITUARY

114 MONOGRAPHS AND PAPERS PUBLISHED INDIVIDUALLY THIS MONTH

117 TECHNICAL PUBLICATIONS

118 SOME RECENT BOOKS

120 FORTHCOMING EVENTS AT SAVOY PLACE

120 DISTRICT MEETINGS

121 CONTENTS OF THE CURRENT ISSUES OF THE *PROCEEDINGS*

121 BRITISH NUCLEAR ENERGY CONFERENCE: FORTHCOMING PROGRAMME

122 ELECTIONS AND TRANSFERS

123 LIBRARY ACCESSIONS

125 ANNOUNCEMENTS TO MEMBERS

129 LONDON REPORT

132 NEWS FROM THE CENTRES

135 NEWS FROM ABROAD

xxxi Index of Advertisers

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THE INTERNATIONAL GEOPHYSICAL YEAR

As many members of the Institution will be aware, scientists throughout the world are now busily completing their preparations to participate in the work of the International Geophysical Year, which is the name given to the period from the 1st July 1957 to 31st December 1958. During this time a concentrated and large-scale study will be made of the physical properties of the earth and its atmosphere and the associated phenomena such as aurorae, cosmic rays, and magnetic and ionospheric storms. This is the third time that a detailed programme of world-wide experiments and observations will have been carried out in an active spirit of co-operation between scientists of all nationalities. The first enterprise of this nature was in 1882–83 and was termed an International Polar Year; it was followed fifty years later by a second co-operative effort under the same name. These, as the title indicates, were concerned specifically with a study of the special phenomena associated with the earth and its atmosphere in polar regions. During the Second Polar Year (1932–33) radio technique was available for investigating conditions in the ionosphere at high latitudes, and successful expeditions were conducted in Arctic regions under the auspices of the International Scientific Radio Union.

The reduction of the interval to twenty-five years on this occasion is an indication of the rate at which scientific research is advancing at the present time; and the deletion of the word 'polar' from the title of the present, third, enterprise is due to the realization that various geophysical phenomena are associated with the earth's magnetic equator, so that observations are required at low as well as high latitudes.

The programmes of research and the general plans for the forthcoming I.G.Y. have been developed by a special international committee sponsored by the International Council of Scientific Unions. The detailed arrangements for conducting the programmes are being made by the various national scientific bodies, of which the Royal Society is responsible for the British participation. The special international committee has held approximately annual meetings in Rome, Brussels and Barcelona (last year), and has formulated programmes of work in the fields of meteorology, geomagnetism, aurorae, cosmic rays, solar and ionospheric investigations, glaciology, oceanography, and seismic and gravity measurements.

As an indication of the interest of the work to the radio and telecommunication engineer, a greatly increased effort will be placed on research relating to the properties of the ionosphere and troposphere, and the manner in which the characteristics of these regions are related to or determined by solar radiation, cosmic rays, the earth's magnetism, and meteorological conditions. A large number of observing stations will co-operate in programmes concentrated on three or four regular world days already selected in each month, and during special world intervals which will be announced from time to time when, from solar or other indications, a period of geophysical disturbance of unusual interest is to be expected. For this work, all the modern radio and electronic apparatus available will be used. In addition to automatic and manual methods, including those of the radio astronomer, for studying the ionosphere, meteor trails and radiation from outer space, a direct exploration of the upper atmosphere will be made by rockets and by satellites, which are being designed to make several circuits round the earth in a few hours.

Included in the activities of the International Geophysical Year, for which the preparations are very far advanced, has been the organization by several nations of some forty expeditions to the Antarctic continent. It is current news that the British expedition, comprising twenty men with a few hundred tons of stores and equipment, that left London on the 15th November 1956 in the M.V. *Magga Dan* has reached the base at Halley Bay in Coats Land at the approximate position 75° 30′ S, 26° 40′ W. This base was named by the Royal Society after Edmond Halley (1656–1741), a great mathematician, astronomer and explorer; and it was established by the advance party organized and sent out by the Royal Society about a year ago. In the same area are other bases set up by Argentina and the United States for work during the I.G.Y.; there is also the Shackleton base, situated in Vahsel Bay, which is the starting point of the British Trans-Antarctic Expedition under Dr. V. Fuchs, who has planned to make a traverse of the South Pole in co-operation with Sir Edmund Hillary, who will be starting from McMurdo Sound on the other side of the continent.

The next two years will thus be a period of great activity among the forty-four nations engaged in this enterprise, involving more than one thousand stations and observatories in all parts of the world; and a great advance may be anticipated in our knowledge of the physical phenomena which are associated with the earth and which play a major part in determining the nature and order of our daily lives.

An Electrical Engineering Review

HIGH-CAPACITY ALTERNATORS FOR POWER STATIONS

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In this review article, Mr. W. J. Carfrae indicates some features of the design and construction of the largest alternators in use in Great Britain and North America to-day. It should be emphasized that the design of such generators is in a fluid state at present, and there is a tendency towards using units of ever higher rating. Within the last three months the Central Electricity Authority has announced the intended installation in 1962 of a 550 MW machine, comprising two 275 MW cross-compounded alternators. The economics of the size of turbo-generators, whether operating from fossil or nuclear fuel, are by no means clear cut, but it seems probable that in this country the cost of generating electrical energy decreases continuously with increasing size of alternator employed. The limit of rating is in fact set by the maximum weight that can be carried on the roads of this country. The 200 MW sets that are to be commissioned by the C.E.A. in 1959 will throw further light on this question of economy of size—a most important one in view of Britain's rapidly growing dependence on electrical energy.

Mr. Carfrae is Manager of the Turbo-Generator Engineering Department of the British Thomson-Houston Co.'s Rugby works.

W. J. CARFRAE, B.SC.(ENG.), MEMBER

Introductory

ALTERNATORS installed in power stations, hydraulic or thermal, are distinguished from the general run of rotating electrical machines by the high outputs of individual units. They are invariably of the stationary armature (stator) and rotating field (rotor) type. Alternators for hydro-electric or Diesel-engined stations are of the slow-speed multi-polar salient-pole type, and for hydro-electric stations may have the shaft disposed vertically with the alternator above the water turbine.

Slow-speed salient-pole machines are not included in this review, which is confined to two- or four-pole cylindrical rotor machines driven directly without intermediate gearing by steam or gas turbines.

In Europe the standard frequency is 50 c/s and alternators therefore run at 3 000 or 1 500 r.p.m. In North America the standard frequency is 60 c/s, and the corresponding generator speeds are 3 600 and 1 800 r.p.m. Other parts of the world have adopted one of these two standard frequencies. In some turbo-generators this difference in frequency has a profound effect on the technical and economic aspects of design.

Nearly all thermal stations in commission to-day are equipped with units rated at 3 MVA and upwards, and at the present time the upper limit of rating may be taken to be in the region of 300–500 MVA. As far as is known, the highest rating on order in Great Britain at the present time is 275 MW.

General Considerations

It is axiomatic that a single machine will cost less than two smaller machines having the same total output, and although the rate of decrease in the *pro rata* capital cost of machines for increasing rating diminishes progressively at the higher ratings owing to increased complication and the necessity of using more expensive raw materials, the principle holds good throughout the range of ratings.

However, operational flexibility and provision for periodic overhaul of generating units necessitate the subdivision of generating capacity. Such subdivision, if carried to excess, will result in excessive cost and low efficiencies. The extent of subdivision required for lowest total cost and best overall efficiency is therefore a matter of nice judgment. Indications are that, for conditions in the United Kingdom, the optimum size of unit is probably of the same order as the largest technically practicable.

The four-pole generator is almost obsolete to-day and will not be dealt with further here. The lower operating speed is not generally favourable to high-pressure turbine design, and the unit as a whole is bulkier and more expensive than a two-pole machine of similar rating. There may be a limited field for machines of this type in special applications, e.g. the low-pressure unit of a two-shaft machine. Modern development has therefore been concentrated on the two-pole generator running at 3 000 (in North America 3 600) r.p.m. The rotor of such machines is a solid steel forging which may, in the largest sizes, have a diameter of some 3 ft 6 in., a body length of 20 ft and, with the shaft ends, have an overall length of 36 ft or more. The weight of such a forging may be 50 or 60 tons. The production of large masses of alloy steel such as this, completely free from any flaw, is a veritable triumph of the steelmaking art. Without the skill of the steelmaker the modern high-speed alternator would not be possible. While various types of composite two-pole rotor construction have been introduced from time to time, it is perhaps significant that none so far seems to have won general acceptance.

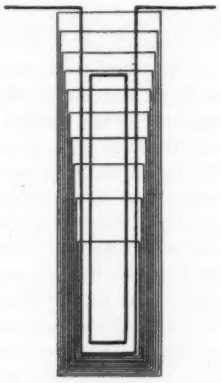
ARMATURE (STATOR) CONSTRUCTION

The basic features of the stator are the core, built up from segmental steel sheets, and the windings of copper

bar insulated with Micanite and carried in slots in the inner periphery of the core. A stator frame is necessary to support the core and windings and provide an enclosure for circulation of the gaseous coolant.

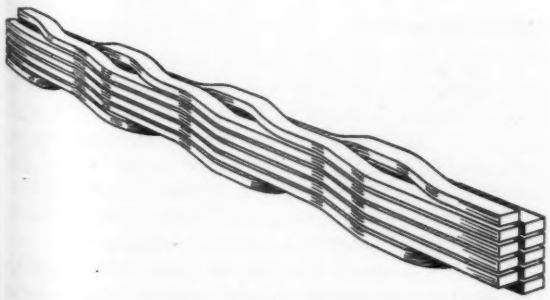
Stator Core

This is built up of slotted segments punched from special silicon-alloy steel sheets, 0·014–0·016 in. thick. The best quality of sheet in use to-day for large alternators has a specific loss guaranteed not to exceed 860 mW/lb at a flux density of 13000 gauss.* Lower losses can be obtained by increasing the percentage of silicon but only at the expense of increasing brittleness. While this is satisfactory for transformer construction, it is liable to result in an undue proportion of cracked punchings as used in machines. Future developments will probably lie in the use of cold-rolled grain-oriented sheet[1] but at present scarcity and high price render it uneconomic. Radial ducts are provided for cooling purposes at intervals along the length of the core, these being formed by I-section spacers spot-welded to adjacent punchings. To ensure satisfactory spot welds and give some additional axial stiffness the punchings next to the ducts are usually made from thicker sheet (e.g. 0·025 in.) of low silicon content.



1 *The pattern of leakage flux across a slot in the armature of a large turbo-alternator*

* The usual method of definition, employing a curious mixture of British and metric units.



2 *A perspective view of a Roebel bar*

The core has dovetails, or the equivalent, cut in its outer circumference, which engage with longitudinal ribs in the frame to provide static support and the necessary torque reaction. It is clamped longitudinally by massive end plates incorporating non-magnetic tooth fingers. Some variations in practice occur here, complete end-plates of non-magnetic cast iron with integral tooth fingers being an alternative to ordinary steel or cast-iron end-plates provided with separate non-magnetic-steel tooth fingers. Screening is often provided at these end plates to reduce stray losses.[2]

Stator Windings

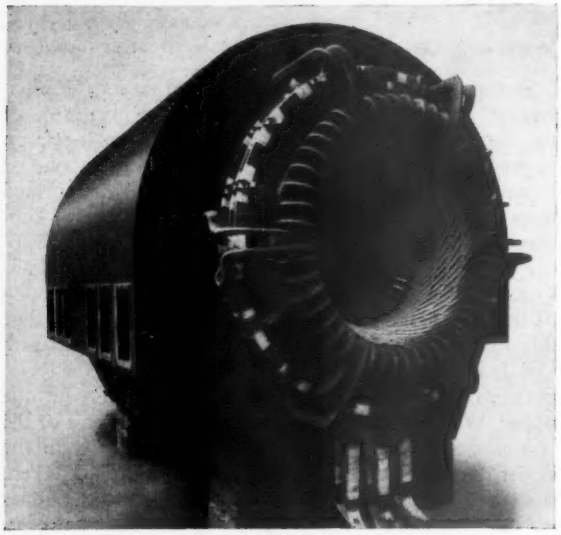
Stator windings for large turbo-alternators (terminal voltages range from 3·3 kV to 36 kV) are invariably of the bar type, formed as a rule from rectangular-section copper conductors. A stator slot may contain one or more conductors, and each conductor may be formed from a single bar or may consist of a number of sub-conductors lightly insulated from one another. Sub-division with transposition is required in most windings to reduce the eddy currents which are set up in the body of the conductor. Fig. 1 shows the pattern of leakage flux round a current-carrying conductor in an armature slot. It is easy to see that the flux linkages with the lower portions of the conductor are greater than with the upper. With alternating current the lower portion of the conductor has, therefore, a greater reactance than the upper portion, and, if corrective measures are not taken, the whole of the current passing will crowd to the upper portion and cause severe overheating and increased loss. This effect is always present in a slotted armature, but it is only for deep conductors in large slots that the effect becomes serious.[3,4] Transposition of the sub-conductors can be effected in various ways, such as cable-laid strands, individual transpositions, and various special types of conductor such as the Roebel bar, which is illustrated (without insulation) in Fig. 2.

A slot may contain any number of conductors, sub-divided or otherwise, but the majority of machines built to-day have an even number of conductors per slot. This permits of the winding being made in two layers, and by a suitable arrangement of end connections, two conductors can be connected in series to form one turn of a stator coil having an effective circumferential pitch less than a complete pole pitch. A single-layer type of winding may have any desired number of conductors per slot but the effective coil pitch is always equivalent to a full pole pitch. This can easily be demonstrated by drawing a winding diagram. Fractional coil pitches, made possible by the two-layer type of winding, give a reduction of stray loss and of harmonics in the generated e.m.f.

Armature windings to-day are invariably of the three-phase type, the conductors being circumferentially

arranged in six groups, i.e. three groups per pole (Fig. 3). By making the coil pitch about 5/6 of the pole pitch, the groups of conductors in one layer are displaced about half a group span in relation to those in the other layer, and this leads to the best results.

In general a fractional coil pitch of $(n - 1)/n$, where n is an integer, will suppress any generated nth harmonic. Only odd harmonics appear in the terminal voltage waveform of a healthy machine on open-circuit, and of these the 3rd, 9th, 15th, etc., will be eliminated from the line voltage by the star-connection usually employed. A 5/6 pitch will reduce the 5th and 7th harmonics to a very low value, and higher harmonics are normally negligible,



3 *The stator winding of a 30 MW alternator*

so that the waveform of a large turbo-generator is to all intents and purposes sinusoidal. The 3rd, 9th, 15th, etc., harmonics may appear in the voltage between line and neutral and, in certain circumstances, can be objectionable, but fairly simple counter-measures are available if required.

In view of the long end windings resulting from the large circumferential pole pitch and the heavy currents that flow under fault conditions, it is necessary to take special precautions in the support of these end windings. They are secured firmly to brackets or rings, and support blocks are provided liberally to ensure that the windings will not deform or be unduly strained if a short-circuit occurs at the machine terminals. It is, in fact, fairly common practice to call for a machine on the test bed to be subjected to a sudden three-phase short-circuit at its terminals when running on open-circuit at normal voltage and frequency.

The number of turns on the stator winding is chosen to suit the output voltage required, and the number of stator slots chosen to suit the winding. Poles can be connected in series or parallel, the series connection being preferred if the rating permits.

Very large machines generally have single-turn coils. The number of slots for a three-phase machine must be a multiple of three, and for practical purposes must be between 39 and 78. Too few slots give an unfavourable pattern of armature magnetomotive force, and too large a number results in excessively narrow conductor sections and inefficient use of the available space. For the largest machines the choice of terminal voltage must be left to the designer if the most advantageous machine is to be produced.

Stator Winding Insulation

Micanite is the only stator winding insulation which is in general use to-day, although different types of bond are employed. Shellac bond with wrapped insulation of the Haefely type is used to some extent, chiefly on the smaller and lower-voltage machines. In the majority of stators a bitumen-bonded Micanite is used. This is applied either as a wrapping on the slot portion of the bar with separate insulation of the end-winding portions or by successive layers of continuous taping from one end of the bar to the other. After application the insulation is vacuum treated, impregnated with bitumen under pressure, and pressed to dimensions in a heated press. This ensures a solid insulation free from voids. The latter are a source of weakness for they may give rise to corona discharge and eventual breakdown.

Stator insulation of this type has a splendid record of freedom from breakdown and any improvement could only be marginal at best. One American firm has pioneered a Micanite bond, consisting of a modified solventless polyester synthetic resin, for which some advantages are claimed.

FIELD (ROTOR) CONSTRUCTION

The principal feature of the rotor is the solid forging which forms the body and shaft ends (Fig. 4). The body is slotted to receive the windings, and steel retaining rings (sometimes referred to as end bells or end caps) are provided to hold the end windings in position against the heavy centrifugal forces experienced.

Rotor Forging

In the larger sizes the forging is made from an alloy steel having an ultimate tensile strength of about 45 tons/in.^{2} and a proportionality limit of about 35 tons/in^2. Adequate ductility is of the first importance together with absolute freedom from flaws of any description. Good magnetic permeability is of course essential.

For smaller alternators a carbon-steel forging having poorer physical properties is usually adequate.

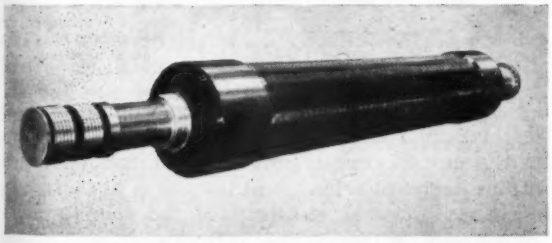
All rotor forgings for use in turbo-alternators are subjected to comprehensive and exhaustive tests before acceptance to ensure, as far as humanly possible, that

they contain no internal defect. The advent of ultrasonic techniques has placed a powerful tool in the hands of the metallurgist, and, as a result, considerable improvements have resulted in forging manufacture and quality. However, the interpretation of readings obtained in this way requires much experience and judgment.

Rotor Design

Rotor design involves mechanical, electrical, magnetic and heat-transmission problems, and the requirements under these headings are often conflicting. Sound mechanical design is of paramount importance. The two principal stresses encountered are centrifugal and bending stresses. The former being steady can be made quite high, about 15–16 tons/in.^{2} at the central bore for the rated speed, and 8–10 tons/in.^{2} at the tooth root. Bending stresses however are alternating, being reversed every revolution, and they must therefore be kept low. Stresses of $\pm$ 1–2 tons/in.^{2} are usual. Also, any steps in shaft diameter must be radiused to avoid sharp internal angles which act as stress raisers.

The end windings of the rotor are retained in position by steel retaining rings. These may be of magnetic or non-magnetic steel. British and European practice favours the use of non-magnetic rings whereas American practice favours magnetic rings. Non-magnetic rings are advantageous in respect of reduced magnetic leakage on the rotor, giving increased output from a given frame size, but on longer machines this factor becomes of decreasing importance. Some advantages are also claimed in the reduction of stray loss by the use of non-magnetic rings.



4 *A complete rotor, showing the slots for the field windings, the end caps and slip rings*

The diameter of the body of the rotor forging is about 3 ft.

On the other hand, higher tensile strength can be obtained with magnetic rings and on this account these may become mandatory for the largest machines. Suggestions have been put forward that titanium or titanium alloys would be eminently suitable for these rings, but present-day knowledge of the properties and behaviour of large forgings of this material is scanty. Experimental work on titanium is in progress.

Critical Speeds

Any shaft having weight and stiffness will have a natural frequency of vibration in any plane through the axis. For large turbo-alternators this natural frequency is almost invariably below that corresponding to the running speed.

In the simplest possible example, if m is the mass of the shaft, assumed concentrated at the centre half-way between the two bearings, ω is the angular velocity and e is the eccentricity of the centre of gravity of the mass in relation to the centre-line of the shaft, then the centrifugal force exerted will be $m\omega^2 e$. This force will produce a deflection d on the shaft, the total eccentricity will become $(d + e)$ and the total centrifugal force $m\omega^2(d + e)$. The force opposing this centrifugal force will be that arising from the internal stresses set up in the shaft material and will be proportional to the deflection d. Let this force be kd. Equating these two forces, we have $m\omega^2(d + e) = kd$. Rearranging, we obtain $d = m\omega^2 e/(k - m\omega^2)$. Inspection of this expression shows that at some value of ω the denominator becomes zero and d is therefore infinite. This value corresponds to the critical speed. Furthermore if, at this value of ω, e is zero, the expression for d becomes indeterminate. In practice this is shown by the fact that a perfectly balanced rotor (i.e. $e = 0$) will run through its critical speed without vibration. However shafts must be designed so that no critical speed lies within 20% of the running speed, or else dangerous vibration could be initiated by any transient disturbance.

In practice, turbine and alternator shafts are coupled together, and the combination will have a large number of critical speeds. Most of these however will be above the running speed and need not be considered. The calculation of the various critical speeds of a combination of shafts is a lengthy procedure.[6] However, developments in computers give promise of considerable help in this direction.

Rotor Winding

This is almost invariably of the concentric-coil type. For a two-pole machine the slot number must be a multiple of four, and the slots are usually distributed in two groups extending in all over about 70% of the rotor circumference. Care is necessary when determining the slot pitching to ensure freedom from undesirable space harmonics in the flux waveform, which is of generally trapezoidal form. Pitch and distribution effects in the stator winding result, however, in the waveform of the generated voltage being practically sinusoidal.

Rotor windings are designed to strike a reasonable balance between excitation current and voltage across slip rings. Usually the slip-ring voltage at rated load is designed to be within the range 110–400 volts.

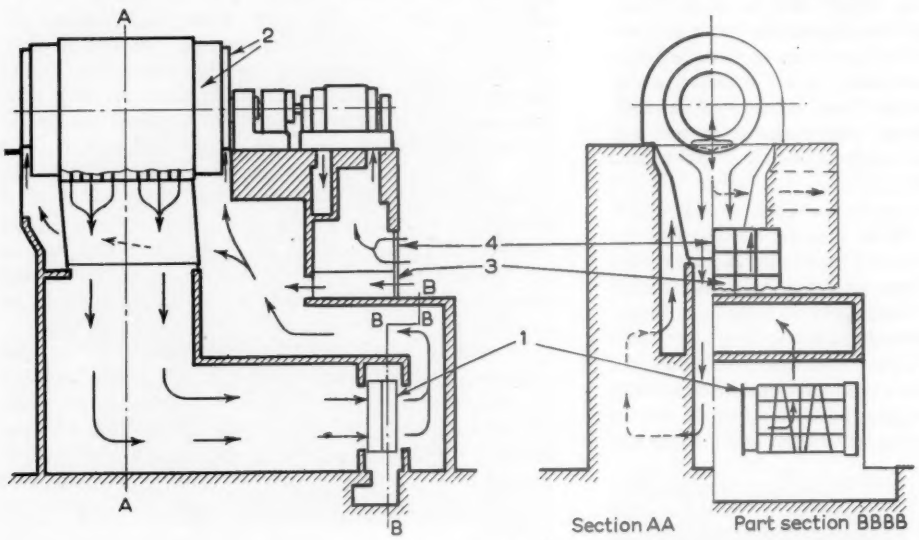
Rotor Winding Insulation

For many years Micanite, with or without mechanical reinforcement, was in universal use for rotor insulation, but in recent years increasing use has been made of asbestos or glass fabric that is bonded with synthetic

compounds of various types. Sometimes a combination of any two of the above has been used. As high voltages are not normally encountered, more emphasis can be placed on mechanical properties; some of the modern synthetic-bonded fabrics have shown quite remarkable wear-resistance, together with adequate electrical and mechanical strength.

COOLING OF ALTERNATORS

The very high speeds associated with limited rotor diameters make the cooling of these machines a problem of some complexity. Intensive circulation of gaseous coolant is necessary, and machines are invariably of the enclosed type with forced cooling. For machines of moderate output up to, say, 40 MW at 3000 r.p.m. (or 20 MW at 3600 r.p.m.) the coolant used is air; this is circulated by powerful fans, which may be mounted on the ends of the rotor or, alternatively, driven by independent motors. With the larger air-cooled machines fan inputs of the order of 200–300 kW may be required. Precautions must be taken to ensure that the circulating air is clean. For small machines it is usually reasonably satisfactory to have a filter in the air inlet, which may be of the viscous-oil or other suitable type. For larger machines, however, a completely closed circuit in which the air is re-cooled by passing through a surface-type heat-exchanger is essential to avoid accumulations of dirt in the ventilating passages of stator and rotor (Fig. 5).



5 *Typical arrangement of ventilation for air-cooled alternator*

1 Air coolers in basement. These are easily accessible and the tubes can be cleaned with the machine in operation at a reduced load.
2 Air circulated by fans attached to each end of the alternator rotor.
3 Make-up air to the alternator closed air circuit supplied through a viscous-type filter.
4 To avoid carbon dust from brushes mixing with the alternator cooling air, a separate air circuit is used for the ventilation of the exciters and alternator slip rings. Engine-room air drawn through a viscous-type filter is used; this ensures clean cooling air at all times.

Hydrogen Cooling

With increase of machine size it became increasingly difficult to ensure adequate cooling with air, owing chiefly to disproportionate increase in windage loss. Attention was turned therefore to the possibilities of other gases for cooling purposes. It was evident immediately that the properties of hydrogen were outstanding for this purpose.

Hydrogen at atmospheric pressure has (approximately) one-fourteenth of the density of air and (weight for weight) fourteen times the specific heat. Therefore, if hydrogen is circulated in a machine instead of air, for equal volumes the windage loss will be reduced to about one-fourteenth of its original value and the temperature rise on the coolant will be the same (neglecting the effect of the reduced windage loss).

For equal volumetric flow at atmospheric pressure hydrogen will pick up about 1½–2 times as much heat as air off any surface for a given temperature drop. In machines of conventional design, where the heat-flow path comprises copper, insulation and iron, the benefit of this improved surface heat transfer is limited by the unchanged thermal resistivity of the solid portions. Nevertheless a substantial reduction in temperature results from the substitution of hydrogen for air as a coolant, with a consequent increase in rating of about 15%. Further improvements are possible by increasing the operating pressure of the hydrogen, but this, of course, results in a slight increase of windage loss.

Hydrogen cooling is probably essential for 2-pole 50 c/s generators with ratings above 75 MVA (40 MVA for 60 c/s machines), and the choice between hydrogen and air cooling for machines of smaller rating is purely an economic one. The special frame construction and auxiliary apparatus necessary for hydrogen cooling result in increased capital expenditure which is largely independent of the machine size, and this extra cost must be balanced against the anticipated gain in efficiency. It would appear that hydrogen cooling becomes justified in 50 c/s systems for units of about 50 MW rating, and in 60 c/s systems[7] for units of about 15 MW rating.

Frame Construction for Hydrogen Cooling

Gas-tight frame construction is obviously essential for hydrogen-cooled machines, and special arrangements are necessary for bringing out the shaft ends. As mixtures of air and hydrogen in certain proportions are explosive, care must be taken to avoid ingress of air to the machine. This is achieved by maintaining the minimum gas pressure in the casing slightly above atmospheric (about 0·5 lb/in.^{2} gauge). Frame casings are built up by welding from heavy mild-steel plate, and all welds are checked for gas-tightness during construction. Heavy end covers are provided which are bolted to the frame with gaskets or other means to ensure gas-tightness. These end covers may or may not carry the rotor bearings. The whole frame structure is designed to withstand any internal pressure resulting from ignition of an explosive mixture in the casing. As, however, the amount of air in the casing is well below the minimum necessary to form a combustible mixture and no means of ignition is normally present, a double mischance would be required before an explosion in the frame could take place. In fact, at the time of writing, no case is known of an explosion in a stator frame.

Gas coolers for hydrogen-cooled machines are mounted in the frame casing, because the arrangement both reduces the total volume of gas in the system and makes it easier to keep everything gas-tight. The axis of the cooler tubes may be either longitudinal or transverse; if transverse, they may be horizontal or vertical. With air-cooled machines, on the other hand, coolers are usually located separately in the machine foundation block.

Shaft Seals for Hydrogen-Cooled Machines

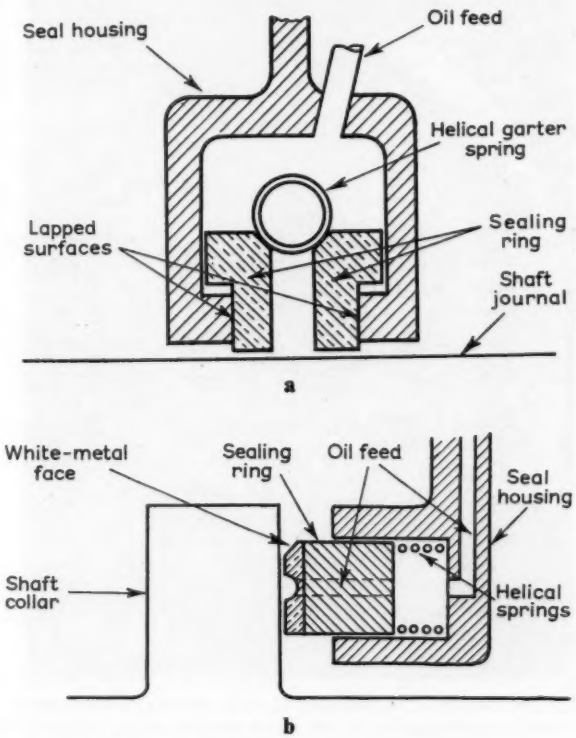
These are invariably of the oil-film type and may be either of the radial- or axial-clearance type. In the former (Fig. 6*a*), two floating rings surround the shaft journal with a small space between them; oil is fed into this at a pressure slightly greater than the hydrogen pressure in the machine casing. These rings are arranged to have a very small radial clearance from the journal, and the oil flow divides, part flowing axially along the journal to the hydrogen side and part to the air side. This film of oil seals off the rotating shaft.

In the axial clearance type (Fig. 6*b*) a ring with white-metal facing is maintained by spring or oil pressure in contact with a collar formed on the shaft, and this sealing ring is provided with oil-feed holes to lubricate the interface between ring and shaft collar. Here again the oil flow divides, part flowing towards the hydrogen side of the seal and part towards the air side.

Oil from the hydrogen side of the seals is drained to tanks, where any entrained hydrogen is separated out and returned to the machine. Oil from the air side of the seals usually returns to the bearing-oil tanks. Sometimes oil for seals, which is invariably drawn from the turbine lubrication system, is vacuum treated before being fed to the shaft seals to minimize contamination of the gas in the machine.

Direct Cooling of Windings

In a present-day machine of conventional design the heat generated in the copper conductors by the passage of current has to flow through the insulation, and in some parts of the machine through the iron core of the stator or rotor before being taken up by the coolant. A considerable reduction of temperature would result if the coolant could be brought into direct contact with the copper conductor. While this has been done to a limited extent on rotor windings with air-cooled machines, the



6 *Shaft seals used in hydrogen-cooled alternators*
a Radial-clearance type. b Axial-clearance type.

relatively low heat-transfer properties of air, and the possible hazards resulting from accumulation of dirt on the surface of the insulation, have combined to prevent general adoption of the principle. However, the advent of the hydrogen-cooled machine changed the outlook completely. The gas-tight frame construction renders impossible the continued ingress of dirt, and the superior heat-pick-up property greatly increases the possible gain.

The principle has been applied in the first instance to rotor windings where only relatively low voltages are encountered and surface leakage across insulation is not a serious problem. Various arrangements using slotted, hollow or grooved conductors have been devised. The gas may enter at each end and leave at the centre of the

machine; it may enter a rotor sub-slot and escape radially through slotted conductors, or it may be picked up from and discharged to the 'air-gap', or a combination of these schemes may be adopted.

The development of rotor cooling schemes of these types has permitted the construction of machines with ratings of the order of 300 MW, which would not otherwise have been possible.

Direct cooling has also been developed for stator windings by the use of rectangular tubular sub-conductors

7 *The stator of a 30 MW 11·8 kV turbo-generator with direct water-cooling of the stator winding*

This machine is a prototype which will be installed at a new C.E.A. power station. Water flows from a header pipe at one end of the stator, passing through separate plastic tubes connected to the conductors at each end of the stator. The total loss in the water in the plastic tubes is estimated to be less than 1 kW, when distilled water of conductivity 2·5 micromhos per centimetre cube is used. With tap water the loss might rise to a maximum of 10 kW.

or by means of internal tubes of thin metal lightly insulated from the stator conductors. These hollow conductors or cooling tubes may contain a circulating gas or liquid (Fig. 7), and the conductor-tube assembly is surrounded by the main high-voltage insulation. Arrangements must be made at the coil ends for the flow of coolant in and out of the conductors and for connections to carry the current to the next coil. (The coolant paths are in parallel but the electrical connection of the half-coils is in series.) This requires careful attention to creepage distances, etc., and if liquid cooling is used insulating tubes must be used to convey the liquid from and to the inlet and outlet headers. In general, it is necessary to adopt direct cooling for rotors at lower ratings than those which necessitate direct cooling of stators.

EXCITATION OF GENERATORS

The excitation of turbo-generator fields (rotors) is usually effected by a small direct-current generator coupled to the end of the machine. Up to outputs of, say, 200 kW these usually run at the same speed as the machine, but for larger outputs a reduction gear is interposed which reduces the exciter speed to 1 000 r.p.m. or thereabouts. This makes an easier mechanical design and reduces the maintenance costs, though at the expense of greater size and cost. Coupling arrangements for exciters usually include some form of flexible drive to prevent transmission of vibration to commutators and brushes.

Occasionally a separate motor-generator set is utilized for excitation, and for a cross-compound (two lines of shafts) generator, where the stators are permanently connected in parallel and the rotors in series, such an arrangement is almost essential to ensure that the high-pressure and low-pressure units run up in synchronism. Whatever type of generator is concerned, the motor-exciter set must be designed to maintain excitation under transient fault conditions on the system. This usually involves the provision of an oversize motor, a flywheel on the exciter set or both together.

Typical Weights and Dimensions of High-Capacity Alternators

Rating	Overall length (between generator bearing centres)	Overall width (over stator feet)	Stator weight	Rotor weight
MW			tons	tons
3	8 ft 6 in.	5 ft 6 in.	7	2½
10	11 ft 6 in.	8 ft 9 in.	22	7
30	17 ft 8 in.	11 ft 0 in.	63	20
100	23 ft 4 in.	16 ft 1 in.	180	32

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ELECTRICAL SCIENCE AND THE ELECTRICAL INDUSTRY

621.3

The position of the chartered engineer in society and the position of the University engineer in relation to industry are subjects of great moment to all in the profession. The author, who is Professor of Electrical Engineering at the University of Bristol, and has had close contact with industry for many years, discusses them in stimulating terms. The following is a shortened version of his inaugural address as Chairman of the Western Centre, which he delivered at the Engineering Laboratories of the University of Bristol on the 8th October 1956.

Professor G. H. RAWCLIFFE, M.A., D.SC., MEMBER

PROFESSIONAL engineering is a curiously blended mixture of science, technology and administration, no one of which would avail anything without an adequate admixture of the other two. To electrical engineering, science is fundamental: it largely consists of the art of producing things which are contrary to, or at least outside, ordinary human experience and are only known to be true or possible because scientists have found them to be so: electricity itself is the most unlikely of all phenomena. Other kinds of engineering deal largely with concepts which a child can understand: everyone is familiar with roads, bridges and water wheels, and even the aeroplane is simple in its objectives and was anticipated by the birds! But most of the apparatus of electrical engineering is quite beyond direct experience: one will never understand the working of an induction motor or a cathode-ray tube by simple observation. It is perfectly true that many kinds of engineering—some, such as road and bridge engineering, as old as the Romans—have been much eased and improved by the advance of science; but they still consist, in large part, of making things within ordinary experience rather than things discovered and extended only by science.

But although science is fundamental to electrical engineering, and all electrical engineers must know some science and some a great deal of science, the proportion—measured by time and manpower—of all electrical engineering effort which is directly scientific is relatively small. The biggest single element in all professional engineering is almost certainly in administration, followed closely by detailed constructional design; and it is just because engineering is an amalgam of so many elements that it offers scope and satisfaction to people of widely differing talents, actuated by very varied motives. None the less, a little leaven (as we are told on good authority) leavens the whole lump, and science is the leaven of electrical engineering, and the whole electrical industry rests, in the last analysis, on the discoveries of a few creative scientific geniuses; and, more immediately, on the labours of a comparatively few well-trained applied scientists. You will perhaps not think it unnatural that I should deal to-day mainly with the scientific yeast rather than with the full-baked engineering product which it yields.

The Creative Element in Electrical Engineering

Every one of us, in the face of the accumulated scientific wisdom of mankind, is properly humbled about his own share in it; but, having said this, there is just one aspect of the matter about which I propose to-night deliberately to strike a slightly assertive note. Senior members of Universities are occasionally told (though less often of late) that they are really amateurs at the game, and that all serious electrical knowledge and skill resides in the electrical industry. This is plain and obvious nonsense, as anyone will see who takes the trouble to cast his eyes around the walls of the lecture theatre and other rooms in The Institution's home at Savoy Place. The men whom The Institution has honoured at the highest level are, in large proportion, people who did their best work in Universities or in quasi-Universities like the Royal Institution. More than any other branch of engineering, electrical engineering is the one which owes most to laboratory study, largely in Universities. Kelvin, Maxwell, Faraday, Hopkinson, Gauss, Weber, Silvanus Thompson, Ambrose Fleming, J. J. Thomson and the rest (it is always easier to speak of the dead than the living): the role of electrical fame is largely a role of academic persons. And, at the lower level of marked professional competence, the contribution of academically trained persons to electrical progress has been and is out of all proportion to their numbers.

When every electrical graduate of every University has about six openings from which to choose his future employment, it may seem strange that I should spend even a moment in pleading the value of the University contribution to electrical engineering. But it is still a fact that, whilst the University is now thoroughly accepted as providing an excellent training for many recruits to the profession, this training tends to be thought of in rather passive terms, as the repetitive communication of standardized information. The electrical profession, except in certain limited sectors, notably among the leading manufacturers, still tends to think of advance in electrical thought and practice as originating wholly or mainly outside the Universities, to be subsequently adopted and transmitted by them. It is indeed a good thing that University teachers should refresh themselves by learning from time to time what industry is thinking and doing, but the reverse is quite often true, though only recently has this been to some extent openly recognized. One recalls the story of the man who, at the end of a long life, asked what prose was, to be told in reply that he had been talking it all his life. In some degree a similar reply could be given to anyone who asked what was the University's principal contribution to electrical engineering: it is what every electrical engineer talks every day of his life.

The Universities, I maintain, are much more than repetitive communicators of accepted ideas to successive generations of students, important though this function is; they are the ultimate source of creative thought in electrical science. Before I consider how well or ill they exercise this latter function, I would like to emphasize how small, numerically, is the University component of The Institution. There are

upwards of 20 000 Corporate Members of The Institution, of whom I suppose not more than 150, at the outside, hold salaried positions on the staffs of all the Universities taken together—less than one per cent of the total. These members have, of course, unusually good opportunities for work of interest to The Institution, and their contribution to its affairs ought rightly to be substantial, but I think it is fair to claim that it is even far more than substantial. There can hardly be any other element of membership equal to less than one per cent of the total which provides so many committee members and office bearers, at all levels, or which contributes so substantially to the proceedings of The Institution, whether that word 'proceedings' be spelt with a large 'P' or a small 'p'. A very considerable part of the printed *Proceedings of The Institution* is contributed by these few University members, out of all proportion to their numbers; and, further, it is significant that though only something like a third of The Institution's total membership are graduates of Universities the great majority of published papers are contributed by authors with University degrees. It tends rather to suggest that the type of education given in a University is the type which is most likely to lead later to creative activity in the subject. If this were not so, and if—so to speak—the Universities did not possess that little bit of something which the others have not got, one might expect creative work in electrical engineering to come equally from all sides of the profession, whereas in fact it does not. There are of course electrical engineers who are highly distinguished for their contributions to the fundamentals of electrical science and practice who have never been near a University, but if the *Proceedings of The Institution* is any guide there is no doubt which way the balance turns.

How then do the Universities differ from being mere purveyors of information, which some think they are and should be? The real answer is that the majority of their teachers are active scholars in their subject, and they speak to their pupils, at least in the later stages of study, not of what they have read in various books but of what in considerable measure they have themselves done, and are still doing, in laboratory or workshop or office. Not only do they speak of what they are doing, but they require their pupils to join in, so that the students themselves may make their first approaches to creative learning and original research whilst still undergraduates.

There are, of course, certain kinds of research which are ill-suited for being carried out in Universities, either because the scale of the apparatus needed is such that no University can really do justice to the work, or because the work itself, though it may have great engineering value, is not intellectually stimulating. Ageing and endurance tests, prolonged load tests and the like are examples of research—better here called investigation—which may be of first-rate practical importance but which, because it cannot be clearly related to any system of logic, has very little educational value. But, on the other hand, there are certain kinds of research which can be done better in Universities than anywhere else; and which, in the doing, add life and vigour to the staffs and senior students of the Universities which cannot otherwise be attained. It is obvious that a very great number of electrical engineers who will serve their profession well in the more standardized forms of engineering activity have no stomach for original work. The world needs all types of engineer, and no one should have forced upon him an intellectual ferment which finds no answering echo in his own nature. But it is the creative scholar, the consultant, the inventor, the writer of treatises, the original experimentalist and people of this sort whom the Universities first exist to foster; and the ultimate and final task of the Universities—the maintenance of the nation's intellectual currency at its full value—must never be forgotten in the hurly-burly of giving routine instruction to large numbers of intellectually rather pedestrian students. In scholarship as in economics, bad currency has a tendency to drive out good.

I have spoken a good deal about the creative side of the electrical engineering work of the Universities, because, though engineering is essentially a creative subject, discussions on engineering education tend to suggest that things are all cut and dried, and all that is necessary is to draw up a syllabus of universal validity. Some such belief has not been without its supporters even in the counsels of this Institution. About two years ago, in common with all other holders of office comparable to my own in this country, I received a circular requesting me to relate the curriculum of the University to the syllabus of The Institution's own examination, together with a request to state my qualifications and those of my colleagues. Behind it all was the suggestion of an external pattern of declared knowledge and standardized action to which we must all conform, and I even wondered whether we should be required to submit ourselves to further examination. Certain protests were made, and it was then agreed that the circular was largely inappropriate to the Universities, but that it should ever have been sent is a straw in the wind of current opinion.

The exercise of creative powers of heart or mind—even on a modest level—is so agreeable and rewarding in itself that no one who is endowed by nature with any creative capacity would willingly exchange the opportunity to exercise it for any other kind of work. No real artist or musician would give up his art for any remuneration: at the worst, he would do hack work for part of his time in order to exercise his talent for the rest. Professor G. H. Hardy—one of the most eminent mathematicians of this century—in his delightful memoir *A Mathematician's Apology* says that, in his view, 'if a man has any genuine talent, he should be ready to make almost any sacrifice in order to cultivate it to the full'. Dr. Johnson was of the same opinion; for, on being told that someone had ridden three horses at once, he declared that 'such a man should be encouraged, for his performances show the extent of the human powers'. I have some sympathy with this point of view; achievement is always achievement however unuseful; but electrical engineers of scientific bent ought to consider themselves exceedingly fortunate in that their work provides them with creative satisfaction as well as their bread and butter—and even a little jam from time to time. Some of you may have read the autobiography of Neville Cardus, the critic for the *Manchester Guardian* and other papers, who combined two oddly-assorted interests—music and cricket. He records there how, finding himself next to *The Times* cricket correspondent at Lord's, they reflected that they were actually being paid for what they were doing, and they commented that being paid to enjoy themselves was too good to be true. There are a considerable number of electrical engineers—I am certainly one—about whom the same is wholly or partly true: fortunate indeed are they.

The satisfaction derived from the exercise of creative powers is closely allied to the pleasures of prediction: one not only makes something new, but one forecasts how it will behave. Spaniards have a phrase for the moment in a bull fight when the matador is about to try to effect a kill: 'the moment of truth' they call it. I have often said to a colleague or a

research student, just before switching on current to a new piece of apparatus, that this was the moment of truth. If the apparatus does not work, one's calculations were wrong: if it works, they were most probably right; though conceivably one may have made several errors which mutually cancel, and about which no one will ever know or care. These are the thrills of electrical laboratory science; and, for myself, nothing would persuade me to accept a position taking me wholly away from the laboratory and its elemental thrills, as to me they seem to be. One has one's frustrations it is true, when nothing happens but the blowing of a high-rupturing capacity fuse, but they are amply outweighed by the successes, which are perhaps sweetened even more by earlier failures.

In his Presidential address to the British Association in Bristol in 1955, Sir Robert Robinson spoke of the prediction of physical occurrences both as 'a perpetual source of wonder' and as a justification of the scientific method. He gave as illustrations the predictions of the existence of the planet Neptune by Adams, of the bending of light in a gravitational field by Einstein, and of the release of atomic energy, which were all shown by theory to be probable before they were attained in practice. Sir Robert might have added another example familiar to all radio engineers: the prediction of electromagnetic waves, by Maxwell, before they were first generated in practice.

But prediction on this grand scale—of totally new physical effects—comes only once or twice in a generation, to scientists of exceptional gifts and with exceptional opportunities, and no one could fairly be advised to study pure science simply in order that he might taste the joys of prediction. The odds would be overwhelmingly on his total disappointment. On the other hand these joys, on a very slightly lower level, are the regular experience of every responsible technical engineer. I know no pleasure to equal that of working out from theory the behaviour of some new or much modified apparatus, supervising its manufacture, and then observing its behaviour on test as a confirmation of one's theory. Occasionally, of course, one has argued wrongly—or some subsidiary effect has taken command of the performance—but this simply means that one must think again and more deeply. None the less, the pleasures of successful scientific prediction are regularly enjoyed at all levels by scientific engineers, and they ought on Sir Robert Robinson's argument to be reckoned as one of the intangible satisfactions of the more scientific branches of electrical engineering, which can relatively seldom come the way of the pure scientist.

The Rewards of the Engineering Profession

It may be objected that the slightly idealistic notions which I have put before you of disregarding wealth and success in order to enjoy creative satisfactions are unrealistic when applied to most people and to most bread-and-butter positions in the electrical industry and profession, and to a good extent this is true. A tiny minority of the population will choose its work in life wholly or nearly independently of the rewards offered, but a much bigger number will be considerably though perhaps not wholly swayed by pecuniary advantage. And this leads me to the one expression of discontent which I intend to permit myself. I stand before you as a man to whom life has been very kind, far beyond my deserts, and I am not likely to be accused of a soured and jaundiced outlook. None the less I am of the opinion that the practice of straight electrical engineering for its own sake in however responsible a capacity does not command the standing which at present attaches to the highest administrative or commercial posts; nor are those who abandon engineering to transfer to such posts always the happier for the change. Though I recognize the great importance of administrative and managerial skills I believe that the nation would benefit if more engineers of the highest calibre continued in the practice of their profession and steps to reduce the relative attractions of commerce and administration seem to me urgently necessary and desirable.

As a nation we have a long and slightly unfortunate tradition that the reward of high professional skill is a highly salaried administrative post: even Newton was rewarded for the *Principia*—the greatest scientific work of all time—by the post of Master of the Mint and thereupon he almost abandoned scientific work. In my view a very learned and technical profession—as electrical engineering actually is—will have, in some considerable degree, to adjust its scale of values if we are to continue to make technological progress.

To some extent, the professions are in permanent competition for the cream of the rising generation. Since it is the essence of wisdom to learn from one's competitors, it is worth observing what happens in other professions. In medicine, esteem is concentrated on those who actually practise their profession rather than on those who administer it. To be a Consultant carries a higher salary and status than being an Administrative Officer to a Hospital Board, or a Medical Officer of Health. In broad terms, in medicine the clinician is king. In engineering, the reverse is true. With rare exceptions, the way to become well-to-do is to give up engineering, and become an administrator, or a salesman. Not only is this the way to become well-to-do, it is the way to all the personal prerogatives of managerial status, and a man of real professional quality is at least as much concerned with the way he is treated as with his salary, once the latter has reached a reasonable level. I think something of this feeling that engineers are inferior to administrators prevents some good candidates from taking up engineering as a profession. They have a half-idea that they are likely to become technicians for hire by business men, or even to become business men themselves, and that they are not entering a learned profession. These fine shades of meaning are difficult to put into words, but I suspect that many of you will agree that there is something in what I say.

To some extent, the world takes a profession at its own valuation. Some of you may know the story about the old lady who asked where the nasty medical students went to, and where the nice doctors came from. I could tell her the answer. The world, like the old lady, thinks or acts as if it thought that all lawyers and doctors are learned and clever men, though some of us who work in Universities—the cross roads at which entrants to and members of all professions meet—know that this is far from being the case. Why then do the public believe it? I suggest it is because members of these professions themselves act and speak as though they believed it to be true. Lawyers even refer to each other in public as 'my learned friend', and whilst this may be partly written off as mere form, it does, I believe, denote their attitude to their own profession. Even those lawyers who are not learned regard erudition as a thing they ought to admire. Similarly, one will never hear a doctor priding himself, or even quietly admitting, that he really knows little about medicine, and that his success is only due to his personality and bedside manner. In his heart of hearts many a doctor will know this is partly true, but he would regard it as an admission of weakness to say so, or even to suggest that it was true of other doctors. The ordinary general practitioner likes to be

thought of as a man who has joined a learned profession by virtue of brain power and knowledge of his subject, and he has persuaded the public that this is so. In engineering on the other hand one still occasionally hears individuals in high place speaking disparagingly of scientific engineers, as mere theoreticians, though latterly their tone has rather altered to a half-affectionate patronage of the 'back-room boy'—in itself a significant change.

It is only when electrical engineers are proud to think of themselves as learned men even when they are not, and to act publicly as learned men are expected to act, that they will stand exactly on all fours with professions which at present are more favoured in the public esteem. A few months ago, I read in *The Times* an account of a speech by Lord Justice Birkett in which he spoke, as he saw it, of the decay in oratory; and he added, what I believe to be true, that the rewards of fluent and attractive speech in any profession or any country are often very great. No doubt this is particularly true of lawyers, but if I had to express in one phrase the change which would most raise electrical engineering in the public esteem I would say an improvement in the quality of speech and writing of the average electrical engineer. I constantly urge this upon our students, not always without effect.

You may have been a little surprised at my use, earlier, of the word 'heart', as well as mind, in speaking of the creative powers of an engineer; but I would like to affirm my belief that emotional drive is that human quality which, next only to a clear understanding of the matter in hand, is the most effective in achieving practical results, in any department of human endeavour. An engineer must, to some extent, have an almost fatherly love for his intellectual and constructional children; and I think the history of engineering shows that an element of fire and emotion is an essential ingredient in engineering success. Further, the quality of an engineer's 'heart' as well as that of his mind, greatly affects his relations with others and thus reacts on his power to achieve results. The Engineering Faculty resembles the Medical Faculty in one respect, which is that—having admitted all applicants of outstanding intellectual quality (10–15% of the total)—we place a good deal of reliance on our estimate of 'heart' and character in deciding whom we shall admit to the remaining places. Though we attach great importance to the intellectual record at school, we do not regard it as quite the only touchstone of merit.

Pure and Applied Science: Their Interrelation

I should like to examine for a moment the relation between physics and electrical engineering, and the arguments for studying either as the entry to a career. Many physicists immensely and constantly underrate the gap between a simple scientific principle and its useful employment in a piece of engineering equipment. To many a physicist, the simple statement that a conductor carrying a current, in a direction perpendicular to a magnetic field, experiences a mechanical force in a direction perpendicular to both field and current is not only (as it is) a statement of ultimate truth: it is a statement of all the truth which he thinks is significant, or which he desires to know. He is quite ready to regard the whole gap between this scientific first principle and the achievement of an efficient, reliable and economic electrical machine with a particular type of performance as purely a constructional matter at the level of *ad hoc* workshop technology. To a physicist an electric motor is an electric motor: the idea of different types has seldom crossed his mind, and, if pushed into a corner, he will usually mutter 'well, of course, there are d.c. motors and a.c. motors'. I have sometimes derived a little innocent merriment from watching physicists, holding more or less this point of view, trying to account for the behaviour of dynamo-electric equipment, or even to perform calculations thereon; and if any electrical engineer desires a little entertaining reading let him turn to the chapters headed (say) 'Applied Electricity' or 'Electric motors and generators' in almost any advanced textbook of physics.

Only after a little seasoning in the hard school of experience does a physicist learn that, after passing on from the primitive scientific concept, there is still a large body of complicated theory to be mastered before one can even begin to think of the constructional side of an electrical machine. I am, of course, not suggesting that all physicists are like this. Many, especially among experimental physicists, are much too wise to view the whole science of engineering with disdain, but such an attitude is not uncommon, especially among theoretical physicists.

The whole tone and doctrine of the physics departments of the Universities of the country tends to be geared to the very latest nuclear discoveries (or attempts at discovery) often still in a very tentative stage. The atmosphere and methods of these departments are well adapted to producing the future Rutherfords and Cockcrofts of the world; and to making, once in a generation, a discovery of far-reaching importance, comparable to that of the discovery of the electron or of nuclear disintegration. By its very nature, pure physical research is bound to be largely abortive: the justification for permitting a great deal of waste effort is that once in a million times the results are of decisive importance. On the physicists' own assumption, and for the purposes they have in mind, everything is doubtless well; but, from the point of view of the immediate national well-being, the situation, in my view, is somewhat unhappy, because it is out of scale with facts.

Electricity in gases, cosmic rays, radio physics, semiconductors and transistors, nuclear energy—I have watched contemporary physicists assuming that each of these branches of knowledge, in turn, was almost the sole object worthy of the attention of a live intelligence interested in physical science. The truth of the matter, of course, is that each and all of them and much more besides need continuous study, if they are to yield progressively increasing benefits for mankind. No doubt, under pressure, physicists would admit this, but they often act as though they believe that classical physics and in particular classical electromagnetism, having been discovered in principle before 1900, is no longer worth the attention of any serious student, despite the fact that a large part of a highly prosperous industry vital to the country depends on classical electromagnetism. If one's notion of science is that only its seminal ideas are significant, one may conceivably come to hold such a belief, but it is completely at variance not only with the limitless use which the world makes and will make of electricity, but with the actual work carried on after graduation by a very considerable number of physicists, who often become engineers by a side wind.

J. J. Thomson is credited with the aphorism that applied science makes improvements, but pure science makes revolutions. There is an element of truth in this, but it would be truer to say that a few pure scientists make a revolution possible at long intervals, provided that a great many applied scientists carry it out continuously. In addition, applied scientists are systematically improving things which already exist in primitive form. Pure scientists are always ready to acknowledge the contribution of constructional engineers who finally carry the plans of applied scientists into action:

they are much more reluctant to give credit to applied scientists who must develop the primitive scientific concept into a full technological subject, before constructional engineers can even begin.

Not only is applied science more necessary than pure science at the present time in the national interest: it is usually much more rewarding, for its own sake, than is pure science. In a strict sense, all pure science is a passive activity: it consists in cataloguing the facts of nature and then explaining the causal and logical relationships between these facts. Some sciences—such as astronomy—can hardly hope to escape from the passive condition: others—electrical physics is a leading example—have passed on from the purely explanatory phase to the discovery of new phenomena, the very existence of which was previously unknown. Hence Lord Rutherford's famous distinction between physics and stamp-collecting. Yet even physics is still, in some sense, a passive activity: nature is still being investigated, though it may be a very recondite and hitherto unsuspected aspect of nature. The moment an electrical scientist decides to use his understanding of nature to design some new piece of useful apparatus he becomes an applied scientist, and is at least halfway to being an electrical engineer.

The number of people in any generation who have either the talent, the taste or the temperament to carry on original research in pure science is very small indeed. Those few who have ought to receive every possible encouragement. But there are numbers of young men every year who could never aspire to become top-level creative scientists who take B.Sc. degrees in physics, and Ph.D. degrees in physics, because of the newspaper publicity on behalf of electronics and nuclear energy. Further, even of those who are potentially of high creative calibre only some can be properly engaged in physics, and a great many ought to turn to applied science, including electrical engineering. Dictators are always a bad thing, but if I were educational dictator in this country, I should prevent any boy taking a B.Sc. degree in physics, let alone a Ph.D., unless he were almost certainly of the first-class honours type, and also of the temperament likely to continue with laboratory work. Further, I would reduce even the number of first-class honours entrants, and a great number of first-class people I would compel to study engineering science, electrical or mechanical, instead. At the same time, I would increase the amount of physics taught to electrical engineers, particularly to those studying for honours degrees.

It is unfortunate that the English word 'pure' carries with it an implication of excellence, almost of moral excellence. 'Pure science' must, by the very meaning of the term, be a better thing than 'applied science': so, in effect, the educated layman is led tacitly to assume. If, instead, the terms 'isolated science' and 'applied science' had been in current use, the force of public opinion would have favoured applied science. Englishmen love to combine abstract ideas and concrete benefits, and thus have the best of both worlds. Few people realize that applied science and technology, so far from lagging behind pure science, are often a good way ahead. The applied scientist is ready fully to use his scientifically trained common sense to produce results in advance of precise knowledge. Technology in its highest ranges should be regarded as science plus experience, and not as a degraded form of science.

Undergraduate Studies and Research

An undergraduate course, however good, is necessarily to a considerable extent an exercise in passive learning, with only a small creative element in it. Plainly, every entrant to a profession must, so to speak, learn one of the various alternative drill books of his profession very thoroughly; but having done this, he ought to make his drill effective by learning to apply it creatively in at least one particular direction. The university research student, in his further two years of study, has an opportunity of concentrated original work under favourable conditions, with direct help and supervision, of a kind that he is not likely to get anywhere else, at least until he has gained a great deal of seniority. The increased capacity for effective action of a research graduate, as compared with a first-degree student immediately after graduation, has to be experienced to be believed; but, as a matter of fact, employers who have once taken such men on to their staffs always want more like them for senior technical posts.

Once an able man has had one to three years in technical industry, a further period of scientific study, under the conditions which only a University really provides, is the ideal crown to his training before finally settling into a productive career. We have had several research students returning for two years to the University—not necessarily the same University—after one or more years in industry, often through the generosity of their employers who have given them salaried leave for the purpose. They have almost always done well. In addition, there are now, as students in the Universities, a considerable number of men who have been in industry for some time before taking their full University course: some of them have come up the hard way, having left school at an early age. Some fall by the wayside, but those who do not are often outstandingly good. Such men are ripe for specialized postgraduate study and research immediately after they have taken their first degree; and what the 'hard way' man, especially, often needs at this stage is a period of intellectual consolidation, during which he can correlate and sort out his strenuously acquired previous experience, both theoretical and practical. We have had several such recently in the Electrical Engineering Department here—also financed by the enlightened generosity of several of the great manufacturing companies—who I think recognize that these men take a little longer to mature than some less distinguished products, but that in the long run they will provide some of the intellectual and personal leaders upon whom manufacturing industry ultimately depends.

I should here like to say how much indebted we in this University are to those electrical manufacturers, from all over Britain, who have helped us in many ways. The most obvious, of course, has been with the supply of equipment for these laboratories, and almost all the larger items have been supplied on some kind of concessionary terms—some of them as gifts. But the help has gone further than this, and the University is now receiving very substantial annual sums to support advanced study and research into dynamo-electric projects, either to buy the apparatus or to maintain the research students who are doing the work, under the supervision of my colleagues and myself.

There are many reasons why I believe that the Universities can often provide specialized postgraduate instruction, especially when allied with research, better than industry can. The most obvious reason is that the first business of a University is to provide instruction: that is what we are firstly paid to do, whereas the instruction of juniors by seniors in industry is necessarily a second- or third-string activity—even for those who are not uninterested in educational activities. Secondly, it has been recognized by a few people for a very long time that original research, because it is an active rather

than a passive form of learning, is a first-class instrument of instruction for an able young man, whatever he may ultimately intend to do. Thirdly, I think it has come to be widely recognized that, even for industrial purposes, the little talents which we dons hide in our academic napkins are not without their value—even, sometimes, their hard cash value. In a word, we sometimes know our subject sufficiently well to be able to give to the young research worker things he cannot get elsewhere, and which will yield fruits in industry later.

I have a copy of a commemorative volume, issued in 1876 to celebrate the opening of new buildings in the University of Manchester, which contains an essay by the then professor of chemistry, Roscoe—a very eminent man—entitled *Original Research as a Means of Education*. 1876 is a long time ago. Dear dirty Manchester, to whom I owe much in many ways! How often has it proved that what Manchester says to-day England will say to-morrow! The chemical industry was the first fully to recognize the value of University research, but there are many signs that the electrical industry is coming to the same state of mind.

I would add here a word of comment on my earlier remark that research students may often, with advantage, work in a different University from the one where they took their first degrees. A first-degree course must not be unduly specialized, and can be taken anywhere, the choice of University being often determined by non-academic factors. That is not to say that, at a particular moment in time, some departments in some Universities are not better than others; but any special merits are those of personalities, circumstances and surroundings: not appreciably those of special emphasis. After the first-degree stage, specialism must come in and each University must have its own particular interests. If anyone comes to us and says that he is interested in wrapping magnetic and electric circuits around each other, for whatever purpose, we greet him like a brother; but, on the other hand, I have several times arranged for one of our own graduates, who had developed a special leaning towards some topic in which none of us is particularly expert, to go as a research student to another University. Mobility in this respect is to be encouraged: it is blessed both to give and to receive, as appropriate. However, whatever the details, I would conclude these remarks about research in Universities with the simple declaration of faith that an undergraduate course which stands alone will infallibly ossify and die in spirit within a very few years.

Conclusion

Ladies and gentlemen: my time and your patience are nearly exhausted, and I have ranged far in these comments on electrical science and the electrical industry. No one can declare his position on any matter without raising some controversy: indeed he who could do so would be a colourless individual. But whatever controversy I may have stirred up, I am sure that I need fear no contradiction in saying that each and all of us, in their own ways, are zealous for the good of the electrical profession and industry.

A few weeks ago my wife and I were visiting, on holiday, the town of Dijon in Burgundy. In a museum there, we noticed a seventeenth-century gravestone inscription which could be freely translated as 'Here lies one who was nothing: not even a member of the academic profession'. If ever I am tempted to overvalue my office I shall recall these words. Now, however, ladies and gentlemen, for one brief year, I am not only a member of the academic profession, but Chairman of the Western Centre of this Institution. Thank you for electing me, and for listening to me for so long to-night.

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FROST PREVENTION IN CONCRETE BY ELECTRICAL MEANS

Frost is the builder's nightmare. Its adverse effect upon the setting of concrete is well known, and, while a cold spell persists, work may be brought to a standstill, with possible financial hardship to both contractors and men. Indeed, throughout the winter it is a constant source of anxiety. In this article the author, who is with the Midlands Electricity Board, describes how electricity has been used in one application to overcome this problem at a low cost.

C. B. COX, ASSOCIATE MEMBER

WHILE extensive mechanization and electrification have been taking place throughout industry during the last twenty years or so, the building industry has remained a Cinderella. By its very nature, building is still largely a manual operation carried out in the open, and it is very vulnerable to adverse weather conditions, particularly frost. During the winter months it is difficult to determine with confidence whether or not the prevailing atmospheric temperature indicates that conditions are suitable for pouring concrete. It is generally agreed that if the mix contains no special additives pouring should not be attempted when the air temperature is below 36° F on a falling thermometer, or 34° F on a rising thermometer. Even so, special vigilance has to be exercised and immediate action taken in the event of rapid changes occurring. It was, therefore, with great interest that the author and his colleagues tackled a problem put to them by a large Midlands firm of building contractors during the very cold spell early in February 1954.

Precast concrete beams were being made in the open in floor moulds, and the specification precluded the use of special ingredients to depress the freezing point, the only protection being a canvas roof to keep off rain, etc. The job concerned was particularly urgent, and it was important that work should not be held up. Moreover, building labour being very scarce, the men had to be retained and paid even if they were not able to work.

The problem was to prevent the temperature of the wet concrete from falling below 34° F by use of electrical heating. Bearing in mind that initially the chemical action

of setting concrete produces some heat, we felt that a load of 5 watts/super-ft (square foot of surface area) would be sufficient to counteract the effect of the frost without pushing up the cost of electricity beyond the economical limit.

Method

We decided that low-voltage equipment should be used to eliminate any danger of shock to building workers unaccustomed to electrical apparatus. At first we thought that the reinforcing steel itself could be used as the heating element, but this proved impracticable owing to its low resistance and to the fact that its many parallel paths would result in a non-uniform and unpredictable distribution of heat. Finally we decided to use insulated low-voltage soil-warming wire consisting of seven strands of steel with a resistance of approximately 0·15 ohm/ft. This was placed in the mould before concrete pouring. Insulated wiring had to be used to prevent any part being short-circuited by the reinforcing steel. The wire, of course, was expendable, the ends being cut off flush when the beams were removed from the mould.

Three types of work of the following dimensions were cast:

(i) Beams, 12 ft long and 6 inches × 12 inches in section (36 super-ft). Weight about 8 cwt.
(ii) Beams, 22 ft long and 6 inches × 9 inches in section (55 super-ft). Weight about 11 cwt.
(iii) Columns, 20 ft long with a 3 ft protrusion at the top at an angle of 30° (84 super-ft). Weight about 1½ tons.

The beams were cast in multiple moulds six at a time, which reduced the effective radiating surface area. The columns, owing to their shape, could only be cast singly, and so were the most vulnerable to attack by frost.

For the first experiment one 12 ft beam was cast by itself, with soil-warming wire laid round the reinforcing between it and the mould sides, this being done to prevent any accidental damage when the vibrator was used to consolidate the wet concrete. A current of 19 amp at 7 volts was used, supplied from a cooker radiant-hot-plate transformer, as shown in Fig. 1, and this current was left on for about 24 hours. In spite of the temperature being several degrees below freezing point for the whole of the 24 hours, there was not a sign of frost damage and the beam was perfect (Fig. 2).

1 *The transformer used in the experiments*

2 *The first experimental casting*

After this encouraging start, six beams were cast in the multiple mould, and then by using two similar transformers in series-parallel connection, a column was successfully cast.

Results

One beam

Total surface, 36 super-ft.
Air temperature during setting, 20–27° F.
Length of wire, 25 ft.
Current, 19 amp. Voltage, 7 volts. Time, 24 hours.
Electricity consumption, about 3 kWh.

Six beams

Total surface, 216 super-ft.
Air temperature during setting, 21–31° F.
Length of wire, 180 ft.
Current, 80 amp. Voltage, 6 volts. Time 24 hours.
Electricity consumption, about 12 kWh.

Two columns

Total surface, 168 super-ft.
Air temperature during setting, 23–27° F.
Length of wire, 130 ft.
Current, 40 amp. Voltage, 20 volts. Time, 24 hours.
Electricity consumption, about 19 kWh.

The experiments described above were successful, and they continued until the advent of better weather. The contractors were very pleased with the results; in fact, work on this particular contract was not halted at all. The costs were very small compared with idle-labour costs, etc., being about 4s. for electricity (at 4d. per kWh) and 3s. for cable, per 100 super-ft of concrete.

Although the experiments were carried out on precast beams, there seems no reason why the same principles should not be applied to concrete cast *in situ*. However, before such equipment could be widely used, it would be necessary to devise a simple method of application. It is suggested that a transformer of about 2 or 3 kVA would suffice, with a primary tapping switch to give secondary voltages of 7–25 volts in steps of 1·5 volts. To give a simple indication of load a primary ammeter would be fitted, together with a nameplate giving the recommended current of 2 amp per 100 super-ft of concrete.

Acknowledgment

The author thanks the Midlands Electricity Board for permission to publish this article.

ARC INTERRUPTION

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Part 2. Theory and Experiment on Gap Recovery

In the second half of their article Dr. Edels and Dr. Crawford examine the mechanism of the interruption and re-ignition of electric arcs in greater detail. Part I was published in December 1956.

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F. W. CRAWFORD, B.SC.(ENG.), PH.D.

THE problems associated with circuit-breaker performancewere discussed in Part I of the article, which indicated that satisfactory circuit-breaker design depends upon a fuller understanding and analysis of the phenomena of arc interruption. Consideration of the many processes involved in arc interruption made clear the extreme complexity of the problem. It was noted in particular that successful interruption depends largely upon the dynamic exchange of many forms of energy in the circuit-breaker gap, and that this energy exchange depends upon both the gap and circuit conditions. The difficulties associated with arc interruption are such that there will undoubtedly be further extensive theoretical and experimental developments. It is likely that progress will be facilitated by an increased study of the separate fundamental processes involved in interruption, and by investigations of particular aspects of gaps under arc-interruption conditions.

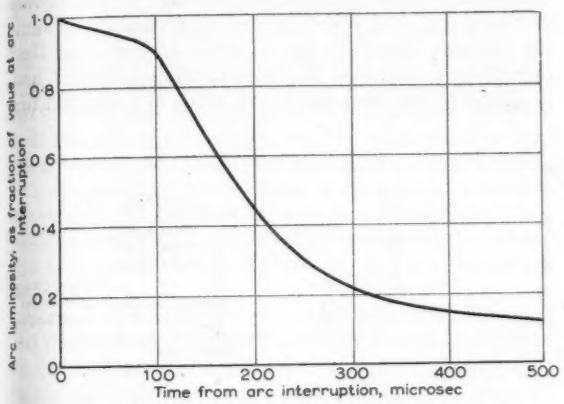
Of the many interesting investigations which may be carried out, perhaps the most important for both the development of circuit-breakers and of interruption theory is the determination of the manner in which the normal gap properties are recovered after current zero. It will be recalled that Slepian in 1928 drew attention to the importance of this subject by his proposition that the success of interruption was controlled by two essentially independent phenomena, namely gap recovery and applied restriking voltage. Although we know that these phenomena are not independent, the concept is of considerable value since arc interruption is in fact largely controlled by these two factors. Very many diverse investigations of gap recovery have been prompted by Slepian's concept. Most of the work, however, has been concerned with a type of investigation initiated by Slepian himself. In this method a measure of gap recovery is obtained by the determination of the voltage required to break down the gap at any instant after current zero. In many ways this is a most suitable mode of measurement, for the breakdown voltage is a function of many

1 *Luminosity decay of long a.c. arc after interruption*
(*Top*) 0·83 sec. (*Centre*) 0·9 sec. (*Bottom*) 1·0 sec.

important gap conditions, such as gas composition, temperature, density and ionization content. Furthermore the method provides data which can be applied almost directly to circuit-breaker development problems. In this article we shall therefore discuss methods for the determination of breakdown characteristics, and survey the data obtained by workers in this field.

Gap Recovery

All gaseous electrical discharges produce properties which are far removed from those associated with the gas in its normal non-conductive state. It is apparent therefore that if a discharge is interrupted, a finite time must elapse before the gas returns to its normal condition. The existence of finite recovery periods is shown, for example, by the remarkable photographs in Fig. 1, obtained by Forrest.[1] These show the existence of appreciable luminosity in a gas at 0·83, 0·9 and 1·0sec after the interruption of a long arc. A further example of luminosity decay is given by Fig. 2, obtained in the authors' laboratories, on the interruption of a 6 amp d.c. arc, the time-base being 500 microsec. Unfortunately, very few data exist on the recovery of individual gas properties after arc interruption, but it is possible to give a reasonable qualitative account of these phenomena.

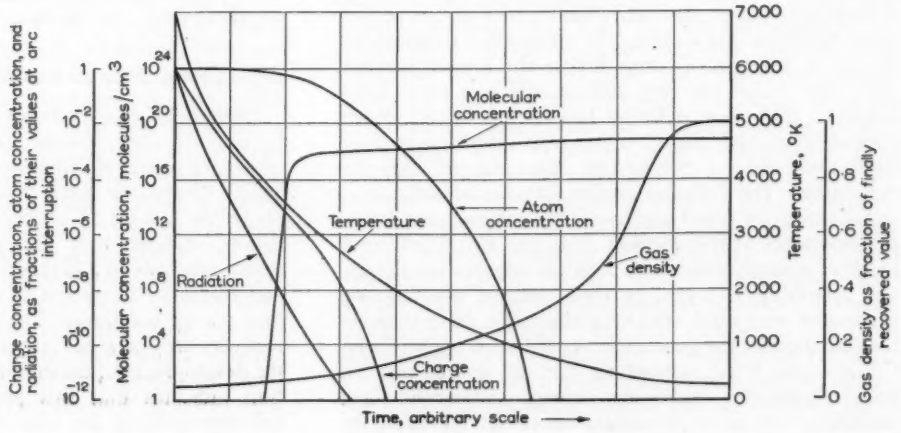


2 *Graph based on oscillogram of luminosity decay after d.c. arc interruption*

Consider the recovery of a plasma section of a d.c. arc operating in hydrogen. We choose this gas since many of its properties are known and because it is an important constituent of the gas produced in an oil circuit-breaker. If such an arc is instantaneously interrupted without the production of a circuit restriking voltage, for example by the introduction of a short-circuit across the electrodes, then the plasma properties will decay freely according to the recovery processes present. If the hydrogen pressure is at least 1 atm the plasma will be in thermal equilibrium, so that its properties will depend upon the gas temperature. Thus, if we assume a plasma temperature decay after current zero as shown in Fig. 3, we can plot the recovery of other gas properties. From the figure we see that the electron concentration falls to 10^{-12} of its original value when the temperature decays from 7000 to about 2000°K. Although this concentration decay is extremely large, there will still persist, at 2000°K, electron concentrations of about 500 per cm^3, a number sufficient to affect considerations of breakdown-voltage value. Similarly the breakdown voltage will be affected by the reduced gas density, which, as shown by Fig. 3, rises only slowly with the decay in gas temperature. With molecular gases, the gas composition is also variable since the high temperatures produce dissociation, and the graph shows that at interruption the gas is initially completely monatomic. The recovery at the electrodes is also time dependent, being primarily influenced by the nature of the electrode material, and its temperature, and by the decay of the electrode space charges. It is also likely that metal vapour from the electrodes will reach the column and affect the recovery.

Breakdown-Voltage Recovery Characteristics

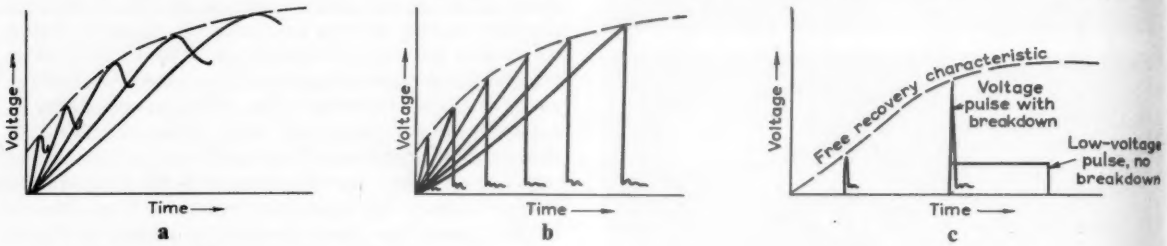
It is well known that the breakdown voltage of a gap is reduced by reduction in gas density, and that the voltage



3 *Free recovery of hydrogen-arc properties*

Gas pressure 1 atm. Concentrations at interruption: ~5×10^{14} electrons/cm^3, and ~10^{18} atoms/cm .

value is also affected by the gas composition, electrode material and ionization content. Thus our considerations and Fig. 3 indicate that the breakdown voltage of a recovering gap will depend upon the instant of application of a restriking voltage. Hence if time control of the restriking voltage is possible we can for each arc and gap determine a time-dependent breakdown-voltage characteristic, which will depict the free recovery of the gap. Normally, however, the restriking voltage appears naturally at current zero and rises at a rate controlled by the circuit conditions. Such voltages can produce post-arc energy input into the gap and hence modify the natural gap recovery, the resultant breakdown voltage being, as in all circuit-breakers, a function both of the arc and circuit parameters. It is still possible, as shown by Slepian,[2] to obtain under these conditions useful recovery characteristics. In his technique the rate of rise of restriking voltage was varied, and the characteristic was given, in accordance with his theory of a 'dielectric race', by the envelope of restriking voltages which just allowed arc interruption, as shown by Fig. 4(*a*). Cobine[3] modified the method slightly by measuring direct the breakdown voltage for different rates of rise of restriking voltage, as shown in Fig. 4(*b*).



4 *Determination of recovery characteristics*
a Slepian's method. **b** Cobine's method. **c** Application of restriking voltage.

However, modifications of Slepian's technique cannot produce recovery data which are independent of the applied voltage. To obtain such data the restriking voltage must be suddenly applied at varying times after current zero. A first attempt at this form of technique was made by Bauer and Cobine,[4] by artificially extinguishing the arc at a controlled time before the normal current zero. The circuit recovery voltage, which is maintained constant, then gives differing breakdown values, which depend upon the period of current interruption, and from such data a breakdown characteristic may be determined. The differing current waveforms and consequent change in initial gap recovery conditions are major disadvantages of this method. McCann and Clark were the first investigators to use separate sources for the arc and restriking voltages. In their method two impulse generators were used, with a variable time delay between the initiation of the generators. Later work by McCann, Connor and Ellis[5] utilized an a.c. arc source and an impulse-generator restriking source. Although these techniques are an improvement on earlier methods, the waveforms of both the current and restriking voltage are not simple and yield breakdown recovery characteristics which are difficult to interpret in terms of the original arc conditions.

In order to achieve both accurate and consistent results and well-defined initial gap recovery conditions it is essential that special current and voltage waveforms should be used. To this end a technique was developed by Edels and Kelham[6] in which a d.c. arc pulse of controlled duration and a linearly rising probing voltage were used. However, with a linearly rising voltage, errors can occur owing to statistical time-lags in breakdown. Furthermore, such a voltage cannot accurately delineate the recovery characteristic. In order to overcome these difficulties the method has been developed further, and, as shown by Fig. 4(*c*), use is now made of a unit-function restriking voltage. A recent paper by the present authors[7] describes the technique and discusses fully the significance and consequences of the waveforms used. It is recognized that this method does not simulate circuit-breaker conditions, but, by using current values and gap conditions comparable with those in particular circuit-breakers, it is possible to obtain results of considerable value for the solution of circuit-breaker development problems. In particular it should be noted that this method yields characteristics which are independent of the applied restriking voltage. Thus the effect on gap recovery of the variation of controlled recovery forces such as gas flow, arc chutes, etc., can be ascertained.

Experimental Data on Gap Recovery

Despite the disadvantages of his technique, Slepian, in his pioneer work, discovered some important properties of gap recovery. He investigated the recovery of an a.c. arc of several thousand amperes which was rotating in air within a stack of copper plates 1/16 inch apart. His results showed that the gap recovered, apparently instantaneously to a breakdown value of about 240 volts, and thereafter recovered at a relatively slow rate to the final normal conditions. The discovery of this initial rapid recovery was of great importance, leading ultimately to the development of the de-ion circuit-breaker. Consideration indicates that this phenomenon of rapid initial recovery is likely for non-refractory electrodes such as

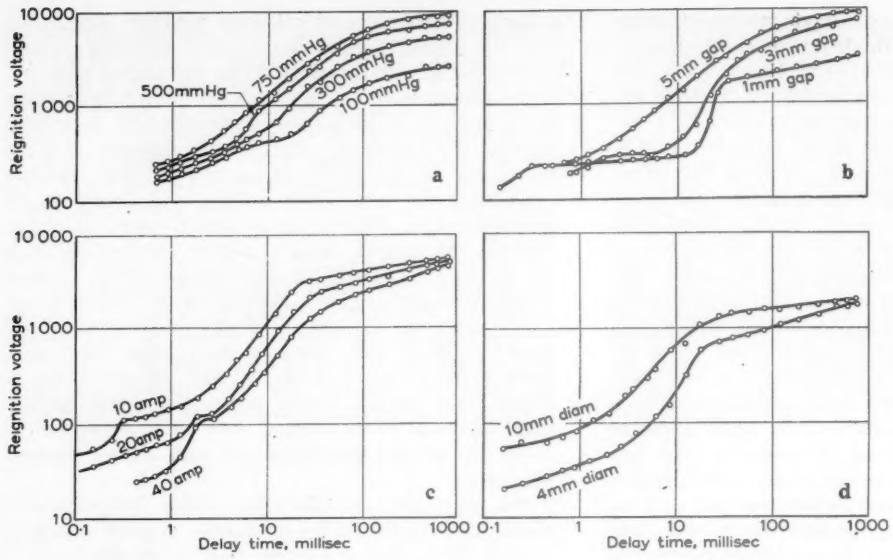
copper. For such metals the arc cathode mechanism most probably depends on the cathode-region space charges, and these can be very rapidly cleared. Furthermore, the rapidity of the clearance will ensure that all the other arc conditions will remain virtually unchanged. In these circumstances, only breakdown of the cathode region is required and this can take place at the minimum spark value. It is likely that with the large ionization content of the plasma such a breakdown will rapidly develop an ordered cathodic-glow region. If this mechanism occurs it is to be expected that the recovery voltage will be close to the cathode-fall voltage of a glow. For copper in air this value is 370 volts. Although this differs appreciably from Slepian's initial recovery value, later work by Todd and Browne[8] gave an initial strength of 360 volts. Their experiments also showed, in air, initial strengths of 280 volts for zinc and 290 volts for iron, which compare well with the glow voltages of 277 volts for zinc and 269 volts for iron. These investigators also observed that with refractory electrodes such as tungsten and carbon, recovery can occur without any rapid initial rise. This result is explicable in terms of the continued thermionic emission which is possible from the hot refractory electrodes.

Browne continued the investigations and concluded that the electrodes can exert a powerful cooling influence on the residual plasma. Thus a decrease in gap length below 1 cm produced for mercury, zinc and brass a rapid increase in recovery strength. His results in general showed that the recovery strength tended to increase with decrease in the boiling point of the electrode material. Refractory metals and those which formed stable refractory oxides gave very low values of recovery voltage. These results are explicable in terms of the energy exchange between electrodes and plasma. Thus refractory electrodes operate at high temperatures and can cause heat flow into the residual plasma after arc interruption, thus reducing the recovery strength, whereas low-melting-point electrodes operate at low temperatures and can extract heat from the plasma after current zero, producing an enhanced recovery. Browne was also the first investigator to determine the recovery of gases other than air. In his experiments an a.c. arc was driven magnetically round a soap-stone slot. He found that for arc speeds up to 200 m/sec the order of best recovery was hydrogen, carbon dioxide, air and nitrogen.

Cobine[3] and his associates, using the a.c. method of testing, found that the electrode surface condition had a pronounced influence on the breakdown recovery voltage. Thus contamination of carbon electrodes, by rare earths for example, reduced the re-ignition voltage by about 25%. Similarly, copper when in an unoxidized condition gave re-ignition in the form of a high-current glow discharge which then developed into an arc. The transitory glow was not produced, however, with contaminated or oxidized copper electrodes. It is clear from this that consistent results can be obtained only with controlled electrode surface conditions. Cobine also showed that a copper electrode could produce cooling of the residual column and therefore an enhanced recovery. The major part of Cobine's work was concerned with carbon electrodes and with the effects of gas pressure on recovery. His results showed that, although the breakdown voltage for a given pressure always decreased with increasing current, the variation with pressure depended on the magnitude of the discharge current. At low currents (<10 amp) the breakdown voltage was found to be proportional to pressure up to about 1 atm. At higher currents the reverse effect could be obtained. Cobine and Power showed that for currents of less than 1·5 amp voltage-pressure linearity existed up to about 7 atm. Experiments on the effects of gas pressure were also made by Hoh and Hanawa[9] for copper electrodes, using currents of 10–110 amp and pressures up to 35 atm. For currents greater than 25 amp they showed that the breakdown voltage rose to a maximum at about 16 atm and then decreased with further pressure increase.

We will now consider the results obtained with techniques employing an artificially delayed restriking voltage. With these techniques many of the properties of recovery already noted were confirmed. Thus, in most of the investigations, increased arc current produced a delay in recovery, Bauer and Cobine showed that recovery was more rapid with copper electrodes than with carbon, and work in the authors' laboratories[6] added further data on the effects of electrode material, arc position and restriking-voltage polarity. Nearly all previous investigations have, however, determined the properties of only small periods of gap recovery. For this reason the present authors developed the method previously described and determined the complete free-recovery characteristic of 10–40 amp arcs between carbon electrodes in air, nitrogen and argon for pressures up to 1 atm. Great care was taken to ensure clean moisture-free gas conditions and controlled electrode-surface conditions. With this technique, repeatable and accurate families of re-ignition characteristics were obtained, and typical sets are given in Fig. 5 (p. 92). Re-ignition was defined as breakdown followed by full arc formation. The figures show increased re-ignition voltage with increase in both pressure and gap separation and reduced recovery with current increase. Fig. 5(*b*) exhibits a remarkable pause in recovery which is maintained for approximately 12 millisec at about 270 volts. Fig. 5(*c*) reveals similar pauses in argon at about 115 volts. It is suggested by the authors that these pauses are obtained because periods of recovery exist in which paths of minimum spark breakdown are always available.

Effects of the electrode–plasma energy exchanges are also indicated by the results. Thus large electrode masses produce increased plasma cooling and enhanced recovery as shown by Fig. 5(*d*). Also the initial rapid cooling of small gaps by the electrode gives rise, as shown in Fig. 5(*b*), to higher re-ignition voltages for the 1 mm gap than for the 3 mm gap for times of less than 1 millisec. Finally it will be observed that the characteristics approach the arc voltage towards current zero (a result expected



5 *Free recovery characteristics*

Carbon electrodes. Duration of discharge 100 millisec.

a Air. Arc current 20 amp, electrodes 4 mm diameter, gap 5 mm, pressure variable.

b Air. Arc current 20 amp, electrodes 4 mm diameter, gap variable, pressure 750 mm Hg.

c Argon. Arc current variable, electrodes 4 mm diameter, gap 5 mm, pressure 750 mm Hg.

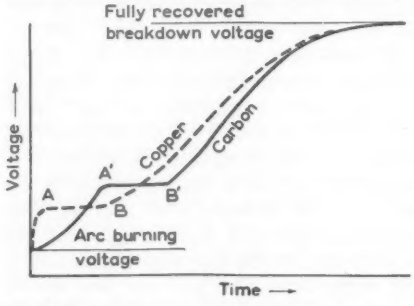
d Argon. Arc current 20 amp, electrode diameter variable, gap 1 mm, pressure 750 mm Hg.

for carbon electrodes) and they persist for 1 sec before full recovery is achieved.

A Theoretical Free Recovery Characteristic

With the experimental data available and from theoretical considerations we can now describe the general nature of the re-ignition characteristic which should be obtained under conditions of free recovery when using a unit-function restriking voltage supplied by a constant-voltage generator. Although the precise form of the characteristic will vary with change in arc and gap conditions, several consecutive stages of recovery exist in which the recovered conditions and consequent form of re-ignition remain essentially the same for all characteristics. Attention must, however, be drawn to the effect on the characteristic produced by non-refractory and refractory electrode materials. We have depicted therefore in Fig. 6 the types of characteristic which may be expected for copper and carbon electrodes, assuming that these electrodes give the same arc burning and fully recovered breakdown voltage.

The first stage of recovery may be defined as that period in which the properties of arc cathodic emission are lost. With copper this recovery is achieved when the electrode space charges are removed. The space charges can disappear in probably less than 1 microsec, owing to the high rates of diffusion and recombination in the gas and at the electrode surfaces. The characteristic should show therefore an almost instantaneous recovery to the point A. With carbon, however, the high temperature of the electrode arc spot and the low thermal conductivity of the material ensure that thermionic emission is possible for appreciable periods after current zero. Re-ignition can occur immediately in the arc form at voltages only slightly greater than the arc burning voltage. The carbon characteristic will thus show a relatively slow recovery to the point A′. In a.c. circuits the gap is subjected to polarity reversal at current zero, so that the arc anode becomes the cathode to the restriking voltage. In the case of carbon, polarity reversal should cause the recovery to A′ to be delayed owing to the higher temperature of the anode spot. Little difference should be observable with non-refractory electrodes.



6 *Theoretical free re-ignition characteristics*

A second stage of recovery should be observable as a period in which the re-ignition voltage remains essentially constant, as shown by the portions AB and A′B′. During this period the cathode region is almost completely de-ionized and at a lower temperature than the plasma, which remains a column of high electrical conductivity. This condition has been observed by Attwood, Dow and Timoshenko[10] with the aid of probe methods for the determination of potential distribution. Full breakdown of the gap is thus ensured simply by breakdown of the neutral electrode gas sheaths, and this will first occur at the minimum spark voltage. Since the gas sheaths are likely to have a non-uniform temperature distribution,

paths of minimum breakdown can exist for appreciable times despite constant energy loss to the electrodes. This phenomenon would be exhibited as the pauses AB and A'B' in the recovery and would indicate re-ignition in the form of a glow discharge at voltages dependent on the gas composition and electrode condition. Recovery beyond this region will occur first for copper since this material has a higher thermal conductivity and lower operating temperature than carbon.

Subsequent recovery beyond the points B and B' will be mainly determined by the recovery of the residual plasma. It is to be expected that the re-ignition voltage will increase gradually to its final fully recovered value as the gas density increases, owing to loss of energy from the plasma. However, for some time beyond B and B', breakdown will also be affected by the presence of ionization caused by the high plasma temperatures. During this period breakdown may be of a cumulative nature, taking an appreciable time for the completion of full arc re-ignition. Such slow breakdowns have been observed by McCann, Connor and Ellis. The final stage of recovery can thus be defined as that period in which the plasma temperature has fallen to a value at which thermal ionization is negligible. In this region normal spark breakdown is to be expected, the breakdown value depending solely upon the recovering plasma gas density and composition.

In a.c. testing it will be appreciated that re-ignition may occur in any of the forms postulated for the different periods of free recovery, the exact form of the a.c. re-ignition depending simply upon the course of recovery and the gap conditions at the instant of breakdown.

Conclusion

The recovery of a gap after arc interruption determines the performance of a circuit-breaker, but the problem of arc interruption is extremely complex and has yielded only partially to theoretical analysis. However, experimental data, particularly on the recovery of breakdown strength, have clarified many of the fundamental stages of recovery, and it is now possible to postulate the general form of re-ignition recovery characteristic, and to describe the course of recovery in terms of known properties of gaseous electrical conduction.

There is still an urgent need for further data if a sound basis is to be provided for circuit-breaker design. Investigations of the individual properties of gap recovery should in particular yield valuable basic information, and the effects on re-ignition characteristics of gap conditions, such as gas flow and arc invironment, should yield data helpful to the solution of individual circuit-breaker development problems.

Acknowledgments

The authors wish to express their appreciation of the interest shown in their work by Professor J. M. Meek and Professor J. D. Craggs, and to acknowledge the generous financial support received from the Central Electricity Authority during recent years for research at Liverpool University on arc discharges. They also wish to thank the Authority for permission to publish Fig. 1.

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OPTICAL STANDARDS: A NEW COMPARISON

The Light Division of the National Physical Laboratory has recently completed a new comparison of its secondary standard lamps with the internationally agreed primary standard light source.

The secondary standards are special tungsten-filament vacuum lamps, in terms of whose intensity the practical unit of light is maintained in this country year after year. The international standard is a small ceramic tube, or cavity radiator, immersed in a crucible full of pure platinum. The metal is first melted and then slowly cooled. During the short period while solidification is taking place, the temperature remains stationary at the freezing point of platinum. At this temperature, at which the observations are made, the inside of the small radiator has, by definition, a luminance of 60 candelas/cm^2.

Upwards of 100 melts and freezes, obtained with the aid of a modern high-frequency induction furnace, were used to amass sufficient observations, which were made by the latest precise photo-electric methods. It is twenty years since the N.P.L. lamps were first calibrated in this way; nevertheless, the values now found agree to within a half of one per cent with the previous ones. Work of this kind remains as indispensable as ever to research and industry alike.

A REVIEW *of the Proceedings, Parts A and B*

SHORT REVIEWS OF PAPERS

On the following pages are some brief review articles based on, and written by the authors of, current Institution papers. The authors have been asked to make these articles, so far as possible, interesting and of appeal to electrical engineers who have no specialized knowledge of the subjects, and the content of the articles is not necessarily confined to the subject-matter of the original papers.

Earth-Loop Resistance

A short review of a Measurement and Control Section paper (No. 2165) entitled 'The Measurement of Earth-Loop Resistance', by G. F. Tagg, B.Sc., Ph.D., F.Inst.P., Member. The paper was published individually in September 1956, and it will be republished in Part A of the Proceedings.

IN THE INTERESTS OF SAFETY IT IS ADVISABLE TO ENSURE that a fuse will blow or other overload protective equipment operate, if a fault to earth occurs on an appliance or machine. One factor which determines whether this will happen is the impedance of the circuit, known as the earth loop, through which the fault current has to flow. Regulation 507 in the thirteenth edition of the Wiring Regulations calls for a measurement of this impedance and recommends a method by which it should be done.

There are a number of factors which have to be considered. The neutral conductor is included in the loop being measured and this neutral may be shared in part with other consumers, and consequently may already be carrying a current of unknown phase and magnitude. This gives rise to a voltage drop between neutral and earth, which, while often only a fraction of a volt, may sometimes amount to several volts, and a value of 16 volts has been recorded. In addition, this voltage is varying continuously and rapidly. Any method used to measure the loop impedance must take into account the presence of this rapidly varying voltage.

A second point which must be considered is the value of the current used for the test. The Regulation states a current 1½ times the rating of the sub-circuit where the test is being made, but, while this is desirable in order to check the ability of the circuit to carry fault current, it is not necessarily the best current to determine the state of the circuit. It is quite usual both for the earth continuity conductor to contain a clamped joint, such as is often made to a water pipe, and for a badly conducting film to form in such a joint. If now a test is made with an equipment which has a low internal impedance, practically the whole of the test voltage will be applied to the bad joint, the conducting film breaks down, a heavy current passes, and the circuit is passed as satisfactory. If on the other hand the testing equipment has a high internal impedance, the voltage applied to the bad joint is low, it does not break down and a high resistance is recorded. In order, therefore, to carry out a satisfactory test it is advisable to make measurements first under conditions such that only low currents can pass, and then such that a high current can pass. If the impedance values so obtained are practically the same, the circuit can be considered satisfactory regarding joints in the earth-continuity conductor, and the value obtained can be taken as that which the loop would have if a fault occurs. If, however, the value obtained with the higher current is considerably lower than that with the lower current, this is an indication of bad joints in the circuit, which should be examined further.

A third point is the question of 'impedance' instead of 'resistance'. The specification of impedance presupposes that the circuit contains reactance, which in this instance would be inductive. The only parts of the circuit which might contain inductance are the earth-continuity conductor and the neutral conductor, but it is very doubtful whether in practice the amount of inductance present is sufficient to produce any significant difference between the resistance and the impedance of the circuit.

The paper discusses these points and the instruments generally available for the test. It is shown, both theoretically and practically, that most are subject to considerable error owing to the voltage drop in the neutral conductor. A description is given of a self-contained instrument which is free from these errors, and which meets as nearly as possible the requirements of an instrument to carry out the test easily and accurately.

621.317.33

Voltage-Transformer Calibration

A short review of a Measurement and Control Section paper (No. 2213) entitled 'The Absolute Calibration of Voltage Transformers', by W. K. Clothier, B.Sc., M.E., Associate Member, and L. Medina, Dipl.Ing. The paper was published individually in November 1956, and it will be republished in Part B of the Proceedings.

VOLTAGE TRANSFORMERS HAVE FOUND WIDESPREAD USE IN electricity generation and distribution for extending the ranges of instruments used for measurement, protection and control. Because of the important role of trans-

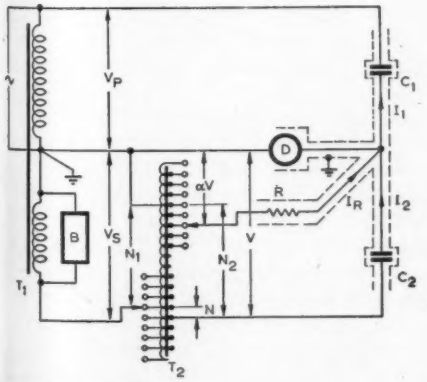
formers in these applications, considerable attention has been given to techniques for determining their errors of ratio and phase angle. A common practice is to measure these properties by comparison with a standard transformer which itself has been calibrated by an absolute method. Transformers serving as reference standards in this way make exacting demands upon the measuring equipment used for their calibration.

In the classical method of carrying out an absolute calibration a resistance voltage divider is used as a ratio standard of small or negligible phase angle. With higher primary voltages, however, owing to stray capacitance effects, this method becomes inconvenient and ultimately impracticable. For accurate measurements the practical voltage limit of the method is about 50 kV.

An alternative method, now generally favoured at high voltages, employs a capacitance voltage divider, or some form of divider using a capacitor in the high-voltage arm. Since the energy loss in an air or compressed-gas capacitor is extremely small, the method is free from the problems of heat dissipation, large size and excessive capacitance that beset the designer of a resistance divider. The design of a high-voltage capacitor, on the other hand, is basically a problem in insulation, and many satisfactory solutions have been described. Commercial compressed-gas capacitors are available in voltage ratings up to 500 kV and above.

The paper describes techniques in use at the National Standards Laboratory, Sydney, Australia, for the calibration of voltage transformers by an absolute method using a capacitance voltage divider. The method is used for all voltage ratios from 1/1 upwards, and the equipment is self-calibrating, in the sense that the ratio and phase angle of the capacitance divider are determined by a self-contained calibration. Owing to the use of stable 3-terminal air capacitors in both high- and low-voltage arms, the capacitance divider provides a highly accurate ratio standard of negligible phase angle.

The principle of the method is illustrated by the simplified circuit shown in the diagram. The ratio of the capacitance divider, C_2/C_1, is first set to the nominal ratio of the transformer under test, T_1. If the transformer had no errors, the detector would balance with the moving contacts on the auxiliary transformer T_2 in their mid-positions, i.e. with no current in resistor R and with the full secondary voltage of T_1 on C_2. In general T_1 will have errors both in ratio and phase angle; ratio errors are balanced by adjusting the primary turns of T_2, thus introducing a slight step-up or step-down of voltage between the secondary of T_2 and C_2. Phase errors are balanced by adjusting the voltage on R, thus introducing into C_2 a component of current which modifies the phase angle of the capacitance divider until it is equal to that of the transformer. The phase angle and the quotient true ratio/nominal ratio are indicated on decade dials.



Simplified testing circuit

N_1 = primary turns on T_2.
N_2 = secondary turns on T_2.
D is a tuned electronic detector.
B is a burden.
C_1, C_2 are air-dielectric capacitors.
R is a phase-circuit resistor.

The values of the capacitors in the voltage divider are considerably smaller than usual—e.g. the capacitance in the low-voltage arm lies between 500 and 6000 $\mu\mu$F. These low values make the use of air capacitors possible in a unit of reasonable size, and at the same time a negligible burden is imposed on the auxiliary transformer T_2. The maximum burden on the secondary of T_1 at rated voltage and at a frequency of 50 c/s is less than 0·04 VA. The accuracy of measurement is 2 in 10^5 in ratio, and 0·05′ in phase angle, and the equipment may be used at any frequency between 20 and 60 c/s.

In their paper the authors describe the build-up technique used for determining the relative values of the capacitors in the voltage divider, an alternative method of transformer calibration and a number of special check tests carried out on the equipment.

621.317.61 : 621.314.222

Surge Protection

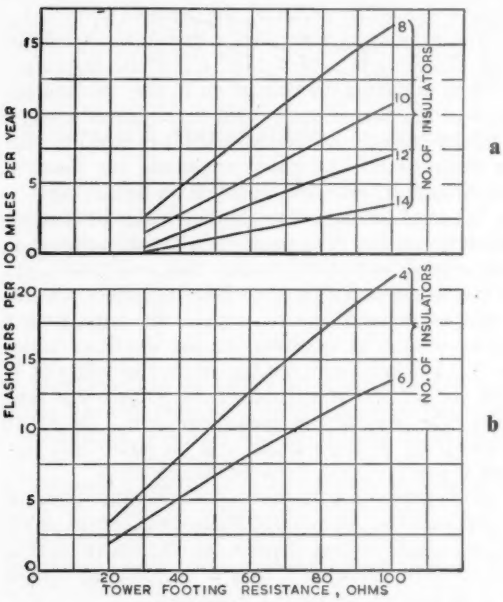
A short review of a Supply Section paper (No. 2158) entitled 'Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33 kV and Above', by A. Morris Thomas, B.Sc., F.Inst.P., Member, and D. F. Oakeshott, B.Sc., Associate Member. The paper was published individually in December 1956, and it will be republished in Part A of the Proceedings.

THE INSULATION OF HIGH-VOLTAGE OVERHEAD-LINE systems comprises suspension, tension, pin, and post insulators, made of porcelain or toughened glass, and air clearances, including protective gaps. By restricting the study to system voltages of 33 kV and above, the problem of selection is simplified in some respects.

It is emphasized that the paper aims at providing guidance to engineers concerned with transmission systems in countries oversea, where a high prevalence of lightning is a major hazard. Practice in Great Britain, where lightning is of minor importance, is referred to only incidentally.

Lightning may strike a phase conductor, earth wire or steel tower. If the earth wire or tower is struck, the

momentary rise of potential may be sufficient to cause a discharge, known as *back flashover*, to one or more of the phase conductors. A line/earth flashover will usually be followed by a power arc which, if not rapidly extinguished, will cause an interruption of the supply or *outage*. It is not economic to insulate overhead lines



Lightning performance of two typical transmission lines according to E.R.A. method (isoceraunic level = 30)

a Span, 885 ft; strokes to line, 67 per 100 miles per year.
b Span, 442·5 ft; strokes to line, 52 per 100 miles per year.

operating at voltages lower than about 300 kV to a degree sufficient to eliminate these flashovers. The procedure adopted is to use earth-wire shielding to reduce the chance of a direct stroke to a phase conductor (the most dangerous contingency), to mitigate the effects of such flashovers as are unavoidable, and to provide insulation sufficient to reduce the outage frequency to a tolerable level.

A convenient measure of line insulation level is the 50% impulse flashover voltage, for which a 1/50 microsec waveshape has been standardized internationally. Tabular and graphical data on the impulse and power-frequency flashover voltages of insulators and air-gaps are given, including the variations which are caused by changes in ambient humidity, air density and the presence of rain. Reference is made to the performance of insulators in polluted air, the use of wood poles as an economical means of obtaining high insulation levels, and the use of automatic high-speed reclosing switchgear for reducing outages caused by follow arcs.

The selection of the line-insulation level for a given system may be logically based on a prediction of line performance. For this there is available either the method of calculation developed by the E.R.A., or the results, obtained by means of an analogue computer, which have been published by the A.I.E.E. The data required for these calculations include statistics of lightning frequency (*isoceraunic level*), of lightning currents and waveshapes, and certain system parameters. Line performance, as predicted for certain typical cases by the E.R.A. method, is shown in the Figure. A comparison of the two methods for a typical transmission line is given in the table.

Comparison of lightning performance of transmission lines with 885 ft span calculated according to A.I.E.E. and E.R.A. methods

Method	Lightning strokes to line per annum		Total flashovers of line per annum
	To towers	To mid-span	
A.I.E.E.	50	50	11·5
E.R.A.	24·6	41	8·0

No rules can be given with regard to the choice of a permissible outage frequency; this is governed mainly by the incremental cost of insulation and the importance of continuity of supply. Experience and personal judgment are also required in selecting higher insulation levels for high crossings, for regions of severe atmospheric pollution, and for parts of the line where access is difficult.

621.315.61 : 621.316.9 : 621.315.1.027.6

Shuttle Propulsion

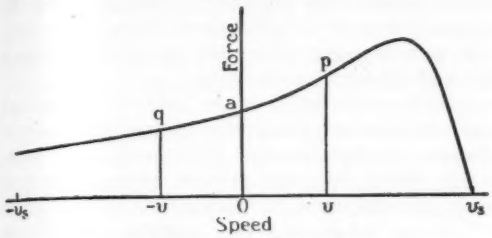
A short review of a Utilization Section paper (No. 1988) entitled 'A Self-Oscillating Induction Motor for Shuttle Propulsion', by E. R. Laithwaite, M.Sc., Associate Member, and P. J. Lawrenson, B.Sc., Student. The paper was published individually in February 1956, and it will be republished in Part A of the Proceedings.

THE STATOR OF AN INDUCTION MOTOR CAN BE CONSTRUCTED in such a way as to produce a linear *travelling* magnetic field. Conducting material placed on such a track will be accelerated to the synchronous speed of the stator field, which is found by multiplying the frequency of the supply by the length of two pole pitches.

In particular a 'rotor' may be constructed on the lines of conventional machine design, having a copper grid inserted in slots in laminated iron. In this case the rotor must be held just clear of the stator track by means of wheels or rollers. Providing the rotor is several pole-pitches long, the operating conditions are not very different from those obtaining in a conventional induction motor, and speed/force characteristics of the form shown in Fig. 1 are possible.

It has been proposed to use such a device for propelling a shuttle across a loom, and experiment has confirmed

the theory that it is possible to use two tracks producing fields travelling in opposite directions in order to obtain a stable amplitude of oscillation without the necessity for any switching device. The theory of such a system may be studied with reference to Figs. 1 and 2.



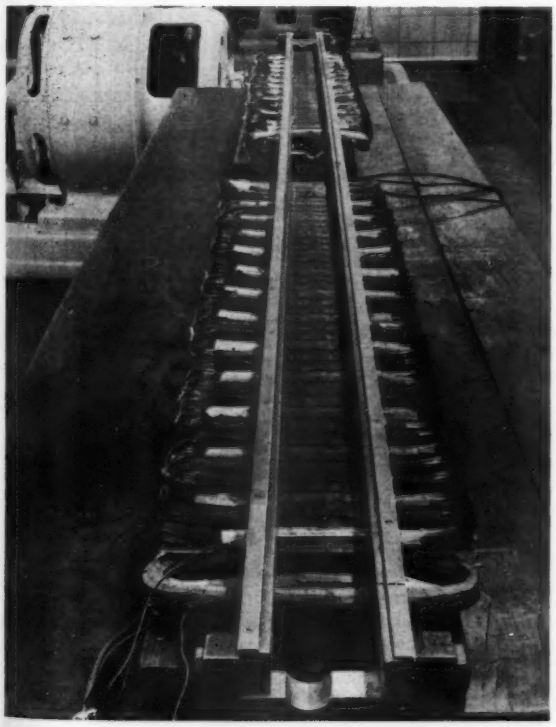
1 *Speed/force characteristic of the motor*

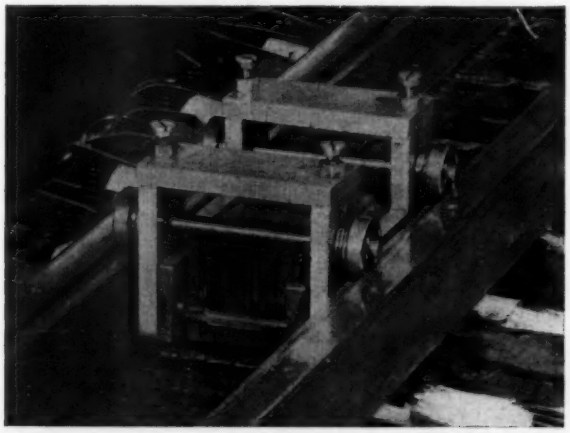
Suppose the rotor is at rest at position A (Fig. 2) corresponding to a (Fig. 1). The rotor will be accelerated towards the centre of the track whilst operating on the part of the curve *ap*, reaching a speed v as it crosses the centre. The rotor will then enter the reverse field and commence operating at the point q on the characteristic, and will be brought to rest under the action of the motor between q and a. Since the deceleration from q to a is everywhere less than the acceleration from a to p, it follows that if B is the second position of rest $x_2 > x_1$. This operation will be continued, the oscillation building up until the synchronous speed v_s is reached during the accelerating part of the motion. By this time the stable amplitude will have been reached, being that distance in which the reversed field can reduce the speed from v_s to zero.

2 *Arrangement of the travelling fields*

In order to reduce the downward magnetic pull on the rotor, which would produce a number of practical difficulties from the weaving point of view, it is proposed to construct a double-sided stator track, between which a double-sided rotor could operate, but for the purpose of the initial experiments a single-sided system was used. Fig. 3 shows the two halves of the track, each being 40 inches long and 3 inches in gauge. The pole pitch is 3 inches. Rotors spanning 1, 2 and 4 pole pitches have been tried and each produced a stable amplitude of oscillation. Approximate equations have been formulated to enable the amplitude and period of the oscillation to be calculated in terms of the parameters of the machine, and reasonable agreement between theory and practice is obtainable. Tests have also been performed when the rotor is working against a constant load force. Fig. 4 shows the rotor in position on the track. The four screws on top are for adjustment of the air-gap.

3 *Experimental layout of the track*





4 *The 'rotor' in position on the track*

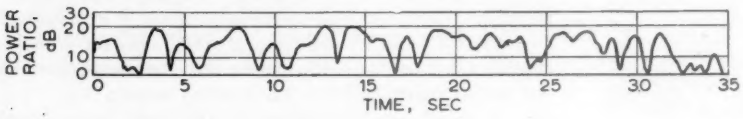
Work is continuing on the possibility of using iron-less rotors, which would be propelled between the halves of a double-sided stator and supported in space by leakage flux, since this appears to be the most attractive system for weaving.

621.313.333 : 621.34 : 677.01

Diversity Reception

A short review of a Radio and Telecommunication Section paper (No. 2239) entitled 'Fading of Long-Distance Radio Signals and a Comparison of Space- and Polarization-Diversity Reception in the 6–18 Mc/s Range', by G. L. Grisdale, Ph.D., J. G. Morris, B.Sc., and D. S. Palmer, M.A. The paper was published in January 1957 in Part B of the Proceedings.

IN THE FREQUENCY BAND 3–30 MC/S, USED EXTENSIVELY for long-distance communication, the amplitude of the signal from a distant transmitter is found to fluctuate.



1 *Fading of single-frequency transmissions*
Shepparton, Australia, 27th October 1954. 1410 G.M.T. 11 900 kc/s.

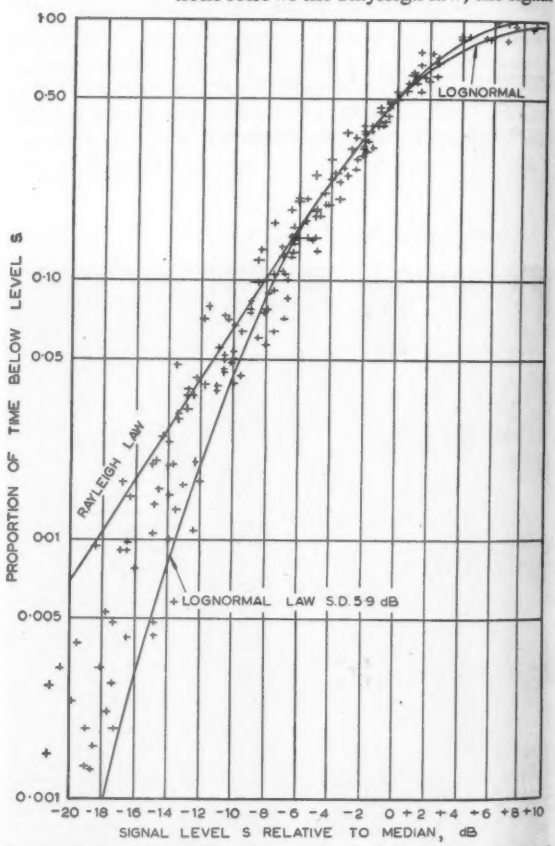
This fading is inherent in the ionospheric propagation of radio waves, and Fig. 1 shows typical examples of the extent and time scale of these amplitude excursions.

A radiocommunication link will fail when the signal falls below a certain value, and in order to prevent this happening when the signal fades very large transmitter powers would be necessary. This solution would in practice be most uneconomical. Another approach to the problem is the use of the technique known as diversity reception in which two signals, derived for example from two aerials placed some distance apart, are used and the best one at any instant is chosen to maintain the communication link. This implies that the fading of the two amplitudes is not simultaneous. Clearly, diversity reception achieves the same effect as would an increase in transmitter power. In their paper the authors discuss and define this power gain, and from the measurements made suggest values appropriate to long-distance radio links.

There are several variants of diversity reception besides space-diversity reception referred to above; for instance the information could be transmitted twice at short intervals to give a time-diversity system. Again, experimental observations on the polarization of ionospherically propagated waves show that in general the polarization is elliptical and varies rapidly in an irregular manner. The fading of the two rectangular components into which an elliptically polarized wave can be resolved is found to be approximately independent and hence they can be used to give a polarization-diversity system. Fig. 2 shows the ellipses obtained when the two components of the wave, one derived from a horizontal aerial and the other from a vertical aerial, are applied to the X and Y plates of an oscilloscope. The changing polarization can be clearly seen. Measurements described in the paper compare the gain expected from the two systems—space diversity and polarization diversity.

2 *Diagram of oscilloscope records showing polarization changes*
Sackville, Canada, 4th November 1954. 1327 G.M.T. 15 090 kc/s. Exposures made at 5 sec intervals.

Theoretical consideration of the gain to be expected from the use of diversity reception leads to the study of three factors on which this gain depends. The first is the fading law, which states the relation between the proportion of time the signal amplitude falls below a given value and the particular amplitude value; it is known also as the probability integral of signal amplitude. For ionospherically transmitted signals a plausible assumption is that the fast component of the amplitude fluctuations follows the Rayleigh law, the signal



3 *Experimental measurement of the fading characteristics of single-frequency signals*
The experimental points fall close to the Rayleigh curve, and reasons are given in the paper why those in the lower half of the graph should fall rather to the right of the curve. The lognormal curve is included for the sake of completeness.
S.D. = Standard deviation.

of instantaneous amplitude S and median value S_0 spends a proportion of time $p(S)$ below the value S given by

$$p(S) = 1 - \exp\,[-0{\cdot}693(S/S_0)^2]$$

The authors describe experiments in which this fading law is verified and the results of many measurements are displayed graphically in Fig. 3. It is concluded that Rayleigh-law fading is a valid assumption for the rapid component of the fading of the signals from distant transmitters.

The gain from diversity reception depends, secondly, upon the proportion of unusable time permitted in the communication link. This proportion is necessarily small —values of 0·1% to 1·0% are typical—because if it becomes appreciable the link is not exploited commercially. For a diversity system using two independently fading signals, each following a Rayleigh fading law, the power gain due to diversity working would be about 10 dB for a signal unusable for 1% of the time, rising to 15 dB when the unusable proportion is 0·1%.

The third factor governing the gain from a diversity-reception system is the correlation between the amplitudes of the signals in the individual channels. In the ideal instance of negative correlation, a decrease in one amplitude would be accompanied by a corresponding increase in the other, and failure of the channel would be much reduced—the equivalent of a large power gain at the transmitter. Considerable experimental effort has been devoted to estimating on the one hand the correlation between the two signals in a dual space-diversity system, and on the other the correlation between the vertically and horizontally polarized components of the wave received at a fixed point. In practice the average correlations were found to be positive.

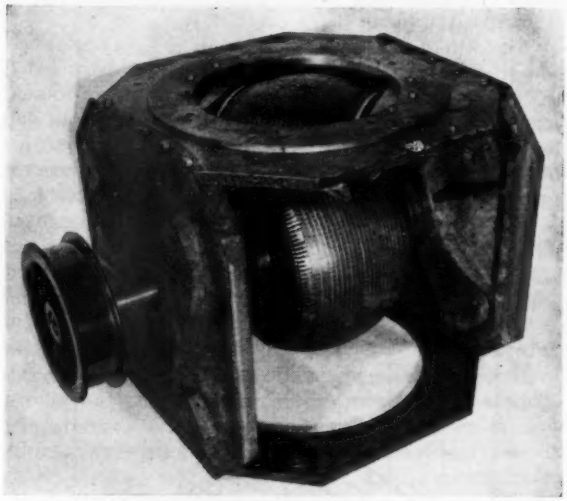
Results are presented suggesting that the gain from a polarization-diversity system is about equal to that from a space-diversity system using two aerials separated by at least 300 m. The polarization system is to be preferred for transmissions from Canada and the United States. It is pointed out that the use of a polarization-diversity system requires the design of satisfactory directional aerials for vertical polarization. Both systems give results equivalent to power gains of more than 12 dB at the transmitter, for a 0·1% unusable-time criterion.

621.396.812.3.029.58

New Motors

A short review of a Utilization Section paper (No. 2097) entitled 'Brushless Variable-Speed Induction Motors', by Professor F. C. Williams, O.B.E., D.Sc., D.Phil., F.R.S., Member, E. R. Laithwaite, M.Sc., Associate Member, and L. S. Piggott, M.Sc., Associate Member. The paper was published individually in June 1956, and it will be republished in Part A of the Proceedings.

IN A RECENT PAPER,* A NEW TYPE OF BRUSHLESS VARIABLE-speed induction motor was described. Machines of this kind depend upon the principle that if the rotor is constrained to move so that any point on its surface



a

b

1 *The early experimental machine*

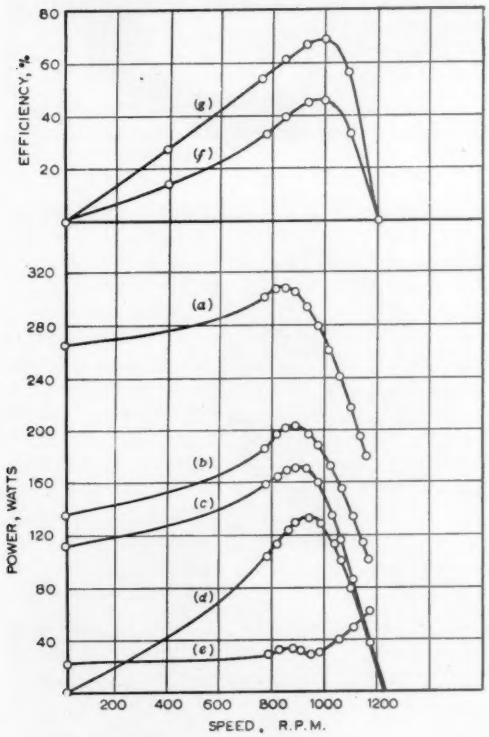
a One stator block in position.
b Stator block removed to show construction.

* WILLIAMS, F. C., and LAITHWAITE, E. R.: 'A Brushless Variable-Speed Induction Motor', *Proceedings I.E.E.*, Paper No. 1737 U, November 1954 (102 A, p. 203).

moves along a line making an angle θ with the direction of motion of the stator field at that point the synchronous speed of the machine is then given by $v_s/\cos\theta$ where v_s is the speed of the field.

One form of motor in which the angle θ may be varied comprises a spherical rotor surrounded by a stator which is divided into blocks, each of which may be rotated separately and yet maintain a constant uniform air-gap between rotor and stator. An early experimental machine of this type is shown in Fig. 1. The rotor diameter is 14 inches. Fig. 1(*a*) shows the rotor and one stator block in position, whilst Fig. 1(*b*) shows the stator removed from the rest of the machine. Provision was made in this machine for four similar stator blocks.

A speed range of 5.5 : 1 was achieved with this machine

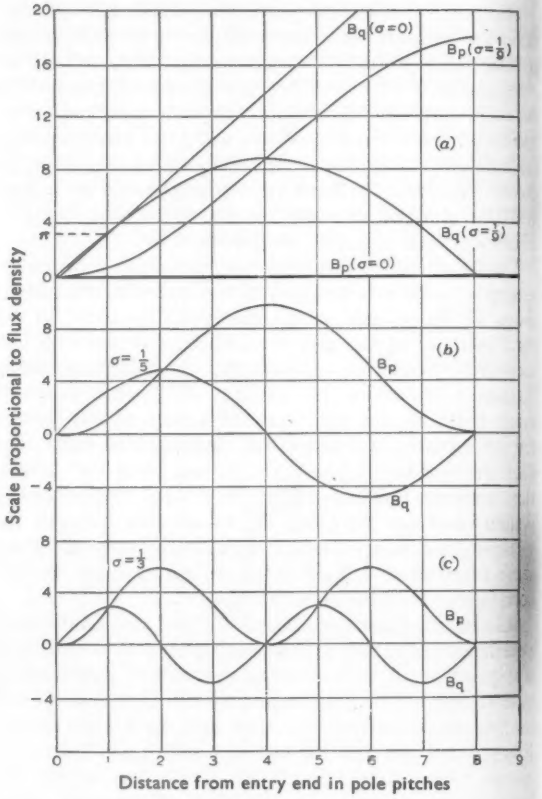


2 *Analysis of losses*

(*a*) Input power.
(*b*) Input power less stator I^2R loss.
(*c*) Synchronous watts.
(*d*) Output power.
(*e*) = (*b*) − (*c*).
(*f*) Overall efficiency.
(*g*) Efficiency neglecting stator I^2R loss.

but its efficiency and power factor were found to be very low. Analysis of the losses of the machine showed that in addition to the losses which could be accounted for by conventional induction-motor theory there were some unaccountable losses which varied with slip in an unusual manner. The graph of Fig. 2 summarizes the experimental results, and the curve *e* represents the untraced losses. Incorporation of search coils under a stator block revealed that although the flux density was sensibly uniform under a block when the rotor was stationary, it differed considerably from point to point on the stator when the rotor was in motion. When running light, the flux density at the end of the stator block, where the rotor bars were entering, was small, but it increased progressively towards the leaving end.

These results suggested a new analytical approach to the problem. Fig. 3 shows the calculated components of



3 *Theoretical flux distribution for different values of slip σ*

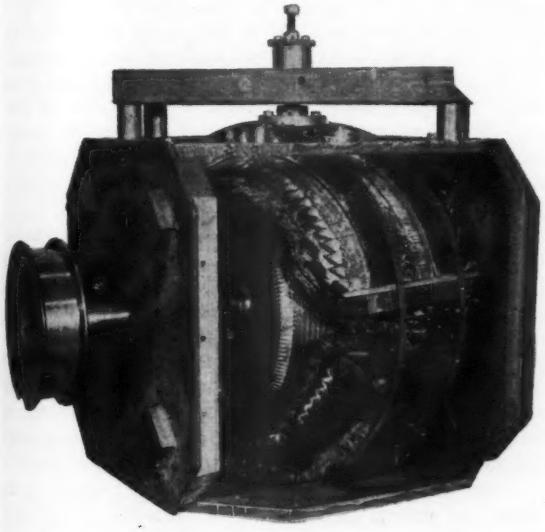
the flux density for a machine whose stator is supplied with constant current, B_p being the peak value of the component of flux density in phase with the stator current, and B_q that in quadrature with it. From the flux equations it is then possible to predict the speed/torque characteristic, the power-factor/slip curve, the peak efficiency and other characteristics of the machine. Experimental measurements support the theory.

One phenomenon which is so far not fully explained is the failure of the rotor when running light to reach the theoretical speed $v_s/\cos\theta$ when the number of poles per block falls below two. It is thought to be connected with the fact that at exit from a block the rotor teeth carry flux away from the stator, which results in magnetic

energy being carried away and dissipated as rotor copper loss during the time the rotor is not under the block.

Broad design criteria have been calculated for spherical machines, and the outstanding feature is that the larger the number of poles on a block, the more efficient is the machine. Increasing the number of poles tends to reduce the power factor, owing to reduction of pole pitch, and it becomes clear that the machine shown in Fig. 1 is not large enough to have both a high efficiency and a good power factor. The peak overall efficiency of this machine can be raised to 61·5% by operating on 400 c/s, but the power factor is then only 0·2.

Development of the brushless variable-speed machine is proceeding along two main lines. A larger machine with a different mechanical layout, permitting increased pole pitch without reducing the number of poles on a block, is being designed. A small prototype machine of this type is shown in Fig. 4. The second line of development lies in replacing the mechanical adjustment of skew used in the spherical machine by an electrical adjustment of skew on a cylindrical machine using phase-shifting transformers. It has already been established that speed ranges in excess of 3 : 1 can be obtained in this way.



4 *Motor permitting increased pole pitch*

Although attention has been concentrated on the 'motoring' phase of the machine, it is clear that similar principles govern its behaviour as an induction generator, and, in particular, that when the angle θ is suddenly reduced, regenerative braking takes place.

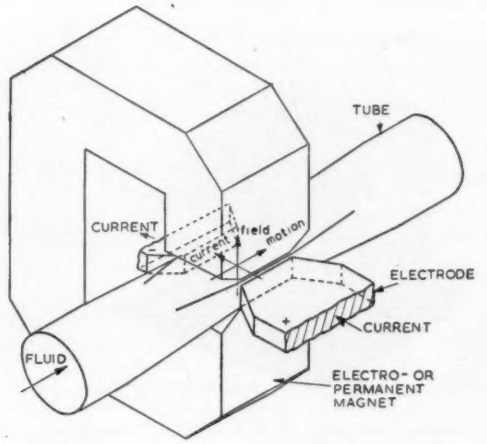
The theory of the short-stator effect is applicable to other types of machine, in particular to the arch-type motor which has been developed in Russia during the past thirty years.

621.313.333

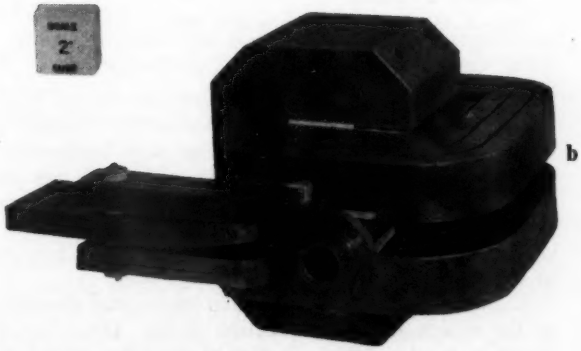
Electromagnetic Pumps

A short review of a Utilization Section paper (No. 2111) entitled 'Conduction and Induction Pumps for Liquid Metals', by L. R. Blake, Ph.D., B.Sc., Associate Member. The paper was published individually in July 1956, and it is republished this month in Part A of the Proceedings.

BECAUSE OF THEIR EXCELLENT HEAT-TRANSFER PROPERTIES and their ability to operate at high temperatures, low melting-point metals are likely to become widely used as coolants in nuclear power applications. To circulate liquid metal, an alternative is provided to the conventional mechanical pump by the electromagnetic pump, which utilizes the good electrical conductivity of the liquid to establish electromagnetic forces directly within it, thus dispensing with the use of impellers, valves, seals or glands, which are particularly troublesome at high temperature with these chemically reactive liquids. Although electromagnetic pumps are sometimes lower in efficiency than mechanical pumps, they are smaller in size, more reliable, often cheaper and require less routine maintenance.



a



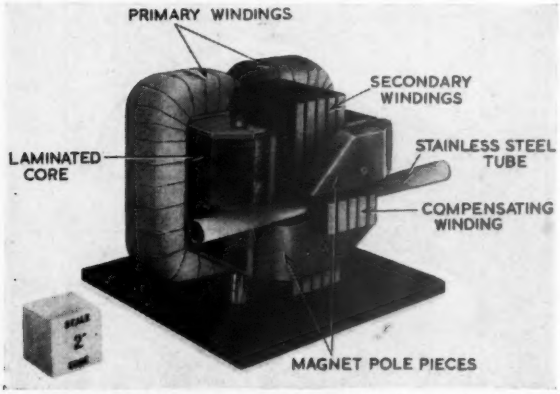
b

1 *Conduction pump in its simplest form*

a Diagram showing principle of operation.
b 10 g.p.m., 60 lb/in.² d.c. conduction pump for bismuth at 500° C.

The d.c. conduction pump is the simplest form of electromagnetic pump and serves well to illustrate the principle of operation. As shown in Fig. 1(*a*) it consists of a metal tube carrying electrodes which conduct current to the liquid metal. A magnetic field is established perpendicular to the current and thus a pressure is set up in the liquid in a direction given by Fleming's left-hand rule. A practical form of this pump is shown in Fig. 1(*b*).

The great disadvantage of the d.c. conduction pump is its inconvenient supply requirements; for example, the pump illustrated requires 4 500 amp at 0·6 volt, while a 2 000 g.p.m., 75 lb/inch^2 pump requires 100 000 amp at 2·6 volts. To provide this current efficiently, it is necessary either to use a homopolar generator or to run a number of pumps electrically in series and to use metal rectifiers. Other associated disadvantages are the large busbar sections, which introduce constructional difficulties, and the need to locate supplies close to the pump. An additional limiting feature of the conduction-type pump in general is that current has to pass through the wall of the tube to the liquid, and hence, good wetting is essential and a high-resistivity film must not be allowed to form on the wall. Apart from these limitations, however, the d.c. pump has a number of useful features. It can accommodate a wide range of liquid metals and



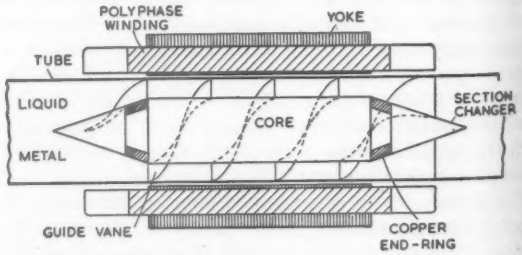
2 *A.C. conduction pump with combined transformer for mercury or bismuth*
6 g.p.m., 15 lb/inch^2, temperatures up to 400° C.

is useful over a wide range of pressures and rates of flow. With the low voltages employed, there is little insulation difficulty, which is a great advantage with radioactive, high-temperature liquids, and the pump, if not its auxiliaries, can be made smaller in size than most other pumps, mechanical or electrical. The efficiency of d.c. conduction pumps varies with size, from a few percent in small pumps to about 50% in large ones.

There are two effects in particular which need attention in the design of the conduction pump. There is the *armature reaction* effect, or distortion of the main field by the current in the liquid metal, which can seriously reduce pump performance and limit the output pressure. Secondly, there is a strong tendency for electrode current to be diverted into the walls of the containing tube and into the liquid metal beyond the region of the pole pieces; here, the current is limited only by ohmic voltage drop, and not also by the induced voltage produced by motion of the liquid in the field, as is the useful component of the current within the field region.

To avoid the supply difficulties of the d.c. conduction pump it is natural to go to a.c. excitation, and Fig. 2 shows a novel form of single-phase a.c. conduction pump. This pump consists of two primary coils which induce a current in a single-turn secondary composed of five parallel paths, each joined separately to the opposite sides of the channel. The route to the far side of the channel is through slots in the magnet pole, and this part of the winding provides compensation for armature reaction. The single-turn secondary can also be regarded as providing the magnetomotive force for the gap field, which is, therefore, substantially in phase with the current in the liquid. Although the magnetic circuit is somewhat complicated, this type of pump is nevertheless simple to construct, and is one of the most effective of its type in small sizes. It has many of the advantages of the d.c. pump, particularly in accommodating a wide range of liquid metals, but there is a sacrifice in size and efficiency; moreover, the pump tends to be noisy, and to withstand vibration it is sometimes desirable to make the tube walls thicker than would be necessary with direct current. Owing to eddy losses in the liquid metal and to iron losses, this pump is not competitive in large sizes at mains frequency, but if the operating frequency is lowered, a.c. conduction pumps, particularly those with separate low-voltage transformers, can be employed in large sizes. Since the low-frequency generator operates at a more convenient voltage it can be located remotely, so that maintenance problems are simpler than with the d.c. pump, which requires its homopolar generator to be nearby, and is consequently difficult to maintain if the liquid metal is radioactive.

There is a further range of a.c. pumps, which come under the general classification of induction pumps and in which the current in the liquid metals is induced either by the main magnetic field or by an auxiliary magnetic field. These pumps are most suitable for fluids of low resistivity, viscosity and density, like sodium, and are not so effective with liquids like mercury or bismuth. Induction pumps, too, avoid the supply

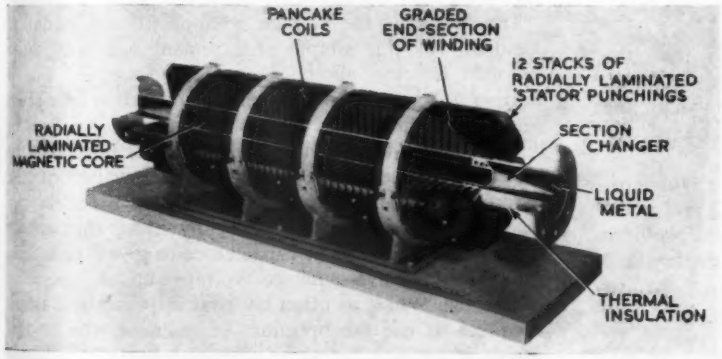


3 *Spiral induction pump*

difficulties of the d.c. conduction pump, and in some instances they also avoid the restriction that the liquid must wet the wall of the tube, for the current can be everywhere within the liquid.

The spiral induction pump of Fig. 3 closely resembles the induction motor in operation. It consists of a conventional polyphase stator, but the rotor punchings are fixed. The gap between rotor and stator is filled with liquid metal which rotates, owing to interaction of the rotating magnetic field and the axial current in the liquid metal, induced at slip velocity. Guide vanes force the liquid to pass through the pump in an axial direction. This type of pump is particularly useful for low-flow, high-pressure applications; the optimum performance of one pump, for example, is in the range 10 g.p.m., 100 lb/inch^2 to 30 g.p.m., 30 lb/inch^2. With sodium at 400°C the maximum efficiency is about 20%. This pump shows an unusual feature due to the axial component of liquid motion, which induces a circumferential current that can cause a marked reduction in pump performance if the spiral angle is large.

A natural development of the spiral induction pump is the linear induction pump, which produces linear motion of the fluid and uses a straight pump tube, which is preferable when the flow rate is high. Fig. 4 shows a sectioned model of an annular form of this pump: this has a polyphase 'stator' winding made up of simple pancake coils, and twelve stacks of radial punchings. The coils embrace a circular tube, in the centre of which is a canned radially laminated magnetic core, the liquid metal flowing in the annular space between core and tube. The magnetic field produced by the winding is radial and travels in an axial direction, inducing a circumferential current in the liquid, again at slip velocity. The interaction of the *radial* field and *circumferential* current produces an *axial* movement of the liquid. It is essential in this design to grade the field carefully at inlet and outlet, if undesirable end effects are to be avoided. Pumps of this type are particularly useful with sodium and similar metals of high conductivity, and can range in size from about 50 to 5000 g.p.m. and up to about 100 lb/inch^2. With linear induction pumps there is again an improvement in performance as the size is increased, the efficiency rising to 40–50% and power factor to 0·5–0·6.



4 *Sectioned model of annular linear induction pump*

621.313.1 : 621.68

New Instruments for Induction Motor Analysis

A short review of a Graduate and Student Section paper with the above title by B. J. Chalmers, B.Sc., Student, and A. R. Daniels, B.Sc., Student. The paper was awarded a Graduate and Student Premium by the Council.

THE PROBLEM OF THE 3-PHASE INDUCTION MOTOR WITH asymmetrical primary connections can be solved analytically by a systematic application of symmetrical-component principles. This elegant method is a particular application of the superposition principle, which can be summarized in the following two theorems:

(i) A single asymmetrical system of 3-phase vector quantities can be replaced by three symmetrical systems of the same frequency as the asymmetrical system and of positive, negative and zero phase-sequence respectively.

(ii) The effect of the asymmetrical system is equal to the synthesis of the separate effects of the three symmetrical systems.

The method simplifies many problems, but a precise determination of performance characteristics may sometimes be tedious because of the complexity of the analytical expressions involved. Instruments for measuring the symmetrical components of voltage and current are useful not only for comparing theory with practice, but also for providing simple and rapid numerical solutions which would otherwise demand laborious computation.

Instruments

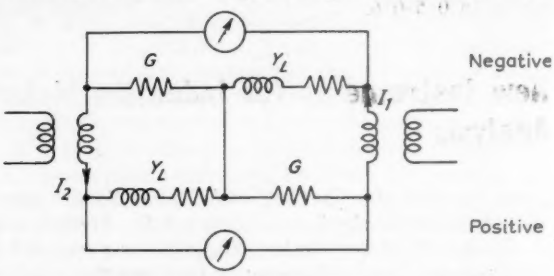
It can be shown that the positive-sequence component V_p of an unbalanced 3-phase voltage system, phase sequence V_1, V_2, V_3, which has no zero-sequence component, is given by the expression:

$$V_p = \left(\frac{1 - a^2}{\sqrt{3}}\right)\left(\frac{V_1 - a^2 V_2}{\sqrt{3}}\right)$$

where a is the 120° operator.

An equivalent verbal statement is that the positive-sequence component is obtained by adding V_1 to the succeeding vector V_2 advanced by 60°, and advancing the resultant, reduced in the ratio 1: $\sqrt{3}$, by a further 30°. When the magnitude of V_p is important, and not its phase, the essential operation is the initial 60° phase shift. This phase shift can be obtained by using the

network shown in the lower half of Fig. 1 in which Z_c is a capacitive impedance equal in magnitude to the resistance R and has a phase angle of 60°. The meter



1 *Instrument to measure sequence components of voltage*
Impedance $Z_c = R\sqrt{60} = -aR$.

current I_m in this circuit is directly proportional to the positive-sequence component of voltage as shown by the expression:

$$V_p = I_m\left[\frac{R + (1 - a^2)Z_m}{\sqrt{3}}\right]\left(\frac{1 - a^2}{\sqrt{3}}\right)$$

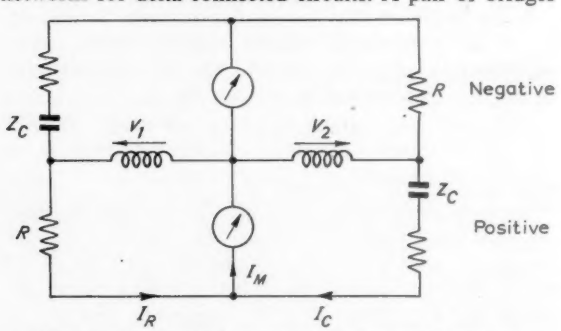
where Z_m is the meter impedance. When Z_m is much larger than R, the expression above reduces to the simple relation:

$$V_p \simeq I_m Z_m$$

and a voltmeter can therefore be used to read the positive-sequence component voltage directly without further calibration. Similarly, the circuit shown in the upper part of Fig. 1 gives a direct reading of the negative-sequence component of voltage.

The corresponding circuit for measuring the symmetrical components of current is shown in Fig. 2 and is the direct dual of the voltage circuit. This network provides an interesting application of the principle of duality, and theoretically it is possible to design a direct-reading instrument employing ammeters. In practice, with ordinary laboratory components, it will usually be necessary to calibrate the instruments employed, with a balanced 3-phase supply used for the purpose.

The networks shown in Fig. 1 are suitable only for star-connected systems but it is not difficult to devise networks for delta-connected circuits. A pair of bridges



2 *Instrument to measure sequence components of current*
Admittance $Y_L = G\sqrt{60} = -aG$.

can be employed over a wide range of current and voltage by using current transformers and voltage transformers of suitable ratios. The bridges can be used either with static or with rotating equipment but their applications so far have been restricted to the following examples, though others are envisaged.

Applications

The particular induction-motor problems which have been investigated with the aid of the instruments are (i) single-phase operation, (ii) single-phase-capacitor operation, (iii) the Ferraris–Arno method for single-phase to 3-phase conversion, and (iv) the Ferraris–Arno-capacitor method for single-phase to 3-phase conversion.

The theory and analysis of the single-phase operation, though relatively simple, are frequently quoted wrongly, and the instruments provide a convincing visual demonstration of the correct explanation. Thus, the positive- and negative-sequence components of current are observed to be equal for all rotor speeds, corresponding to equal forward and backward rotating magnetomotive forces at all speeds. The positive- and negative-sequence components of voltage, on the other hand, are seen to be equal only at standstill, which shows clearly that the oppositely rotating fluxes are equal only at zero speed.

The fact that the voltage components are equal at standstill for this simple arrangement accounts satisfactorily for the absence of starting torque. For a starting torque to be developed, a capacitor is connected between two terminals of the machine. The analysis of this arrangement is complicated, and it is not easy, for example, to determine the numerical value of the required optimum capacitance by calculation. It can readily be found experimentally by using the voltage bridge and adjusting the capacitance to give a minimum value of negative-sequence voltage under operating conditions. When, as often happens in practice, it is not desirable to use the optimum capacitance, the bridges enable a compromise to be effected between conflicting demands of economy and technical efficiency, a problem not always suited to analytical methods.

The basic Ferraris–Arno single-phase to 3-phase convertor is of some historical interest. A two-machine system leads to analytical expressions which yield performance characteristics only after much tedious computation, whereas the bridges enable the degree of unbalance to be investigated by direct experiment. It is, for example, immediately obvious that the magnitude of the negative-sequence component is such that some form of static balancer is desirable. In the Ferraris–Arno-capacitor system, a capacitor is used in exactly the same way as with a single machine, but again the labour involved in determining the performance characteristics without some form of computer would be prohibitive. It is a simple matter in practice to find the optimum value of capacitance, since all that is required is to reduce the observed negative-sequence quantities to their minimum values.

621.317.77 : 621.313.334

More Power from Niagara

A note on a Supply Section lecture (No. 2204) entitled 'The New Sir Adam Beck Generating Station at Niagara: a Major Canadian Hydro-Electric Development' delivered by R. L. Hearn, B.A.Sc., D.Eng., M.E.I.C. The lecture is published this month in Part A of the Proceedings.

IN THE JULY 'JOURNAL' (p. 439) a brief account was given of the Supply Section meeting on the 16th May 1956 at which Dr. R. L. Hearn delivered his absorbing lecture on the second Sir Adam Beck power station at Niagara. The shortened version of the lecture published in the *Proceedings* is mainly an account of the civil engineering work of the station and is recommended to any engineer to whom the subject appeals.

The photograph reproduced here is an aerial view of the two major generating stations on the Niagara river which have been built by the Hydro-Electric Power Commission of Ontario. Water from the two canals is redistributed at the cross-over point (top centre) and flows to each forebay. The switching station is located on the island formed by the canals and forebays. 621.311.21(71)

SYNOPSES OF PAPERS

Half-Speed Motor

A synopsis of a Utilization Section paper (No. 2231) entitled 'A Stator-Fed Half-Speed Synchronous Motor', by R. L. Russell, M.Sc., Associate Member, and K. H. Norsworthy, B.Sc., Graduate. The paper is published this month in Part A of the Proceedings.

IT IS WELL KNOWN THAT AN INDUCTION MOTOR WITH AN asymmetrically connected secondary circuit will run at a fractional slip rather greater than 0·5 but that the asynchronous performance is not wholly satisfactory. The defects arise chiefly, though not entirely, from a rotor field component which rotates with a small angular velocity $(1 - 2s)\omega$, and is responsible for reflecting undesirable low-frequency currents into the primary supply system. These disadvantages are avoided by superimposing a stationary magnetic field which fixes the $(1 - 2s)\omega$ field in space and thus compels the rotor to run at $s = 0{\cdot}5$, i.e. at exactly half speed. Further, the power factor can be controlled by altering the d.c. excitation in the usual way, and good efficiencies can be achieved. Test results are quoted for three different types of rotor and compared with a first-order theory which provides suggestions for improved rotor design and further developments. 621.313.334

Moving-Coil Regulator

A synopsis of a Supply Section paper (No. 2203) entitled 'The Moving Coil Regulator: a Treatment from First Principles', by Professor G. H. Rawcliffe, M.A., D.Sc., Member, and I. R. Smith, B.Sc., Graduate. The paper is published this month in Part A of the Proceedings.

A PARTICULAR TYPE OF MOVING-COIL REGULATOR, OF exceptional ingenuity, has found wide application over the last fifteen to twenty years, but it is believed that no rigorous analysis of it has previously been carried out. It is thought that the theory given in this paper, besides being rigorous, also facilitates calculations on the performance of the regulator, and test results have shown that the theory is fully and closely supported by practical performance. 621.314.214

New Emphasis on Variety Reduction in Industry

In the autumn of last year a renewed effort was made to interest British manufacturing firms in the advantages of reducing the variety of the components and end products which they use and make. Under the auspices of the British Productivity Council, and with the support of the British Standards Institution and The Institution of Production Engineers, a series of meetings was held in industrial centres up and down the country. They took the form of public meetings, and of discussion groups of senior managers in local firms. The moving spirit at them was Professor Harold W. Martin, from the Rensselaer Polytechnic Institute of New York. He is at present a consultant to the European Productivity Agency, which has been organizing a drive for greater productivity through variety reduction in other countries as well as Great Britain. Educated at Manchester College of Technology, Professor Martin trained as an electrical engineer, and since his graduation in 1926 has had much experience as a design engineer, sales engineer, technical editor, and management consultant. From 1947 he has been in charge of production engineering in the Management Engineering Department of the Rensselaer Institute.

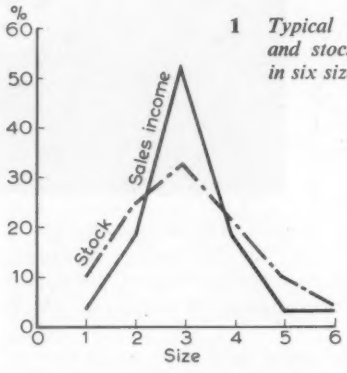
Professor Martin has a most happy knack of explaining management techniques in simple terms. Anyone who has listened to him cannot but admire the lucid common-sense and the practical advice which he dispenses, as pointers to ways that a firm may usefully increase its productivity. The kernel of his recent series of addresses has been to bring home to industrial firms the concept of the 'Three S's'—Simplification, Standardization and Specialization. Briefly, *simplification* implies simplification of each product, of the range of products, and of the manufacturing and selling processes; *standardization* implies using standard materials, parts and sub-assemblies, and standard procedures, costs, and yardsticks of performance; and *specialization* implies concentration on a limited number of products, with the use of specialized equipment and workpeople under high-output conditions.

These ideas have been expounded by management consultants for some years, and the terms were defined in the report of the Lemon Committee on the Standardization of Engineering Products in 1949. But in many medium-size and small manufacturing firms in this country the concept has made little or no headway. 'We've always done it this way' is a valid excuse for continuing to do it in the same way. The recent drive has therefore been aimed particularly at such firms. Many of these may not have standards officers, and their managements may feel too enmeshed in the day-to-day running of the firm to find the time for the necessary research and analysis on which a simplification or specialization decision must be based, without a prod from someone outside the firm.

A typical discussion in the B.P.C.'s recent series of meetings took the form of a one-day seminar at Letchworth, Hertfordshire, under the title 'Productivity through Simplification'. This followed a public meeting on the previous evening at Stevenage, both meetings being organized by the North Hertfordshire Productivity Association; Professor Martin was the principal speaker at each.

Some 30 managing directors, sales managers, production managers, etc., from local firms took part in the seminar. After a short introductory welcome by the President of the Productivity Association, who is the managing director of a Letchworth firm, Professor Martin proceeded to expound the principles of variety reduction and how to set about introducing them in an industrial firm. A few of his salient ideas are noted here, although it is appreciated that they may find their main application in consumer-goods industries.

Professor Martin's main thesis was that in many firms one or two products produced the lion's share of the sales; there were many other products in the firm's catalogue to which much design, manufacturing and sales effort was directed but which brought little return. Firms should concentrate on what they could sell easily. Whenever one tried to introduce this idea one met the rejoinder that a firm would be sacrificing customer goodwill by ceasing to make certain products



1 *Typical relation between sales and stock of a product stocked in six sizes*

that had long been part of its range. But, in Professor Martin's view, this question of 'what the customer wants' was more vexed than it appeared at first sight. He had found that wholesalers often had a far bigger range of common products (e.g. domestic) than any of the comparable retailers they served, who each interpreted 'what the customer wants' according to a different pattern. He cited the instance of a German manufacturer of saucepans who offered 13 sizes of the same design of saucepan, with diameters from 12 to 36 cm in 2 cm steps. Could it be established that housewives minded whether they bought a 22 cm or a 24 cm saucepan? Was it not rather that for historical reasons different retailers put on show different sizes, with no one retailer carrying the complete range? Again, it was always true that sales managers would like to sell what they had not got to offer, and manufacturers should be careful not to extend their range unprofitably.

But in many concerns variety reduction was directed at components and sub-assemblies. It did not automatically imply lack of variety in end-product, or put a brake on initiative in design. 'Maximum range of end-products from the minimum number of components' was the design target to aim at. An American refrigerator firm was formerly making a range of about 100 different end-products with 17 basic design sizes. By redesigning for the maximum degree of interchangeability, with standard panels and doors, a range of about the same number of end-products was produced from 11 design sizes. There was a variety reduction of 35% and an increase in productivity (average lowering of cost) of 30%.

A firm analysing its sales records in relation to products manufactured would often find that about 20% of the

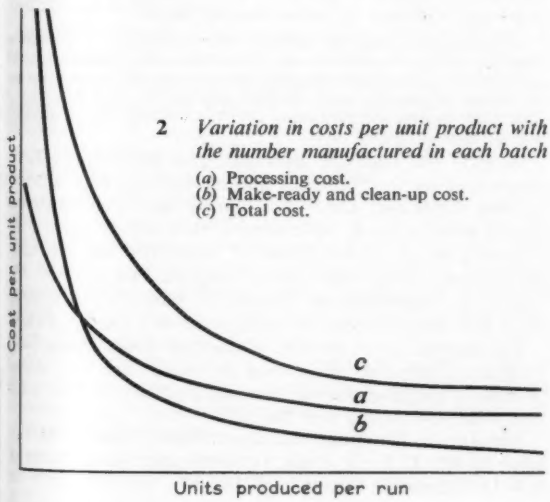
products accounted for 80% of the sales. This was so prevalent in industry that management consultants even spoke of the 80–20 law. But before concentrating one's output on the successful products it was necessary to analyse the profit contribution of each product. Certain of the popular items might be popular because they were priced too low and made little contribution to profit. Another important point was stock. Analysis of the relation between sales and stock often showed that the stock of the fast-selling items was too small (Fig. 1), and this implied that too much working capital was tied up in slow-moving items. Insufficient stock might even deflate a sales peak such as that shown in Fig. 1 for the most popular size.

One of the general truths emphasized by Professor Martin were the advantages of handling large numbers of a product at all stages. The typical variation in cost with length of run is shown in Fig. 2. In this connection he had some pertinent things to say about the organization of manufacture in terms of flow, rather than batch, production.

Professor Martin ended his address by pointing out that the action he advocated should ideally be undertaken on behalf of management by 'standards engineers' trained in the particular techniques. He was completing his British tour by conducting a week's intensive course at Manchester to interest technical college teachers and industrial managers in this work.

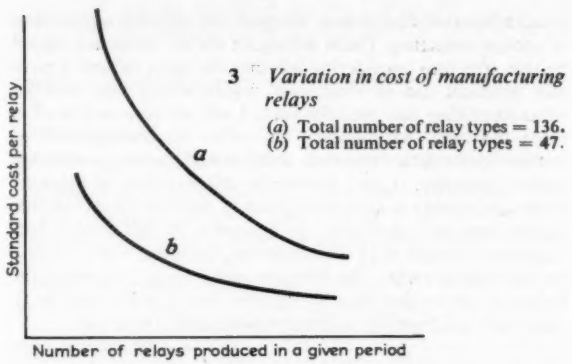
The remainder of the morning session at the seminar was occupied by a local case study. The managing director of a furniture firm in Letchworth described how they had successfully changed in the last few years from traditional methods of designing and manufacturing furniture to unit construction. Productivity, output and turnover had greatly increased.

The afternoon session opened with a second case study, this time an electrical one. The chief standards officer of a local engineering firm, which uses electrical relays in large numbers for the machines it manufactures, described how the number of different types of relay in use had been successfully reduced. The firm makes all its own relays, which resemble, say, the Post Office 3000 pattern, and there are two basic variables distinguishing different types—the coil and the contact pile. An investigation was first made to find out how many different relays were in use in the firm's products. This showed that



2 *Variation in costs per unit product with the number manufactured in each batch*

(*a*) Processing cost.
(*b*) Make-ready and clean-up cost.
(*c*) Total cost.



3 *Variation in cost of manufacturing relays*

(*a*) Total number of relay types = 136.
(*b*) Total number of relay types = 47.

there were 33 coils and 25 contact piles used, and the number of their combinations actually manufactured was 136. There were three main reasons for this large number: (i) historical development; (ii) availability of certain relays at the prototype stage of a new machine; and (iii) lack of information inside the firm about the types in production. Careful analysis allowed a decision to be made to concentrate future production for new machines on 4 contact piles and 13 coils, with 5 extra contact piles and 5 extra coils to take care of existing commitments. The total number of types was reduced to 47, with 27 types accounting for 90% of the production. A graph (Fig. 3) of the cost of relays in terms of the units produced per period bore out Professor Martin's curves (Fig. 2). But although some saving in cost of relay manufacture resulted, the main object of the action taken was to simplify machine maintenance and design.

The programme for the second half of the afternoon session comprised a discussion and two summings-up—by a management consultant, Mr. N. G. Asbury, and by Professor Martin. One of the points raised in the discussion was finance; a speaker thought that the chief difficulty of British industry during the coming years might be the obtaining of sufficient capital, and this led to emphasis on the fact that proper simplification and standardization can release much working capital in an industrial firm. On being asked about the heavy electrical industry, where there is a great deal of tailor-made production, Professor Martin produced some convincing wall diagrams to show the success that a British manufacturer of circuit-breakers had attained in standardizing his sizes and reducing the number of different components for them. Another electrical example, this time a light-current one, came from a Norwegian telephone company which had recently investigated the number of keys made for the switchboards it produced. In the company's catalogue there were listed 150 different types of key, of which only 86 had been used in the previous five years. By a simplifying and standardizing process the 150 were reduced to 22, with a variety reduction of 85% and a cost saving of 30%.

Professor Martin describes his work generally as 'management engineering', and many will feel that this is not the best umbrella term to cover the application of variety reduction in Britain. There are too many kinds of 'engineering' already. If variety reduction is engineering, 'production engineering' is surely the right term for it. This slight criticism does not, of course, detract from the value of the work.

Many of Professor Martin's dicta may appear to be truisms. But case studies and other evidence show that much of British industry has not yet taken such truisms to heart. There is great latent possibility of bigger productivity in the

smaller firms of this country, through the vigorous application of variety reduction. Those managers whose minds are jogged by this note into considering whether the ideas behind it have any practical use in their own organizations may wonder what steps they can usefully take. Lack of time and staff is often the ogre that bedevils any effort by management to initiate the necessary research, analysis and planning to change evolved practice. It may be wise to call in a firm of management consultants to gain man-hours as much as to gain skilled advice. But as a first step, an approach to the British Productivity Council at 21 Tothill Street, London, S.W.1, would be well worth while. The Director will be glad to give all the help and advice that he can. Another useful step would be to read two short and up-to-date publications. These are:

1. 'Variety Reduction.' Two papers by Professor Harold W. Martin (British Standards Institution and The Institution of Production Engineers, September 1956, 5s.).

2. 'Some Results of Variety Production.' (British Standards Institution, November 1956, 5s.).

In the first, Professor Martin lucidly expounds his ideas. In the second there are some interesting British case histories, under the actual firms' names, including two from the electrical manufacturing industry. Even those traditional managers, who act by instinct, experience, and 'flying by the seat of their pants' (to quote a reviewer in last month's *Journal*) cannot to-day ignore the written word as a means of communicating ideas of importance to them.

ARS MARTIS COMES

'Art is the companion of war' reads the motto of the regiment known as the London Electrical Engineers, whose history is briefly described in this article. To mark the Diamond Jubilee of its formation a dinner is being arranged, and it is hoped that many engineers who served in the regiment will be present.

THE anniversary of the formation sixty years ago of the London Electrical Engineers will be celebrated by a Diamond Jubilee Dinner at the Tavistock Rooms, Charing Cross Road, on the 27th April 1957.

A group of scientists established a military unit in 1896 to further the technical development and adoption of electrical equipment in the British Army. The volunteers were known as the Corps of Electrical Engineers, under the command of Major John Hopkinson. They later won their first honours in the South African war at Leenwspruit in 1899, when the officer commanding, Colonel Crompton, was awarded the C.B., and four N.C.O.'s won the D.C.M. The Institution warmly congratulated the Corps after its return to England. The Territorial Force absorbed the unit in 1908 and in the First World War its members were called upon by many branches of the services on account of their technical ability.

Between the wars the London Electrical Engineers for the first time were given a number, the 11th (L.E.E.) Anti-Aircraft Battalion, which was changed in 1923 to the 27th (L.E.E.) A.A. Searchlight Battalion, Royal Engineers. They specialized in the development of searchlight technique. As such the unit were called out in full strength for the Munich crisis in 1938.

The Second World War found the battalion manning the A.A. defences in 1939. The establishment had then grown to nearly two thousand officers, N.C.O.'s and men.

In August 1940 the battalion became the 27th Regiment of the Royal Artillery, and were still permitted as a special honour to retain the letters L.E.E. as part of their description. The regiment sailed from Liverpool on the 15th December 1940. The convoy, with some 30 000 men and their equipment desperately required for North Africa, was attacked on Christmas Day by the German cruiser *Von Hipper* and after nine weeks arrived at Suez via the Cape.

For over four and a half years the four batteries (304, 305, 306 and 390) of the 27th Regiment distinguished themselves along the length and breadth of North Africa and the Western Desert, operating in Crete, Syria, Lebanon, Palestine, Sinai, Egypt, Cyrenaica and Libya. In most of the trouble spots one battery, a troop or even a detachment would be found.

The battery from Mitcham Lane, Streatham (304), maintained a stand on the island of Crete against the airborne might of the German Luftwaffe. From the strength of 10 officers and 433 N.C.O.'s and men, only 2 officers and 79 other ranks returned to the headquarters in Egypt; the rest remained prisoners of war until the end of hostilities. This was undoubtedly the most adverse incident in the regimental history. Yet honours were won in defeat; the Battery Commander was appointed an O.B.E., others gained the M.M., and several mentions were made for gallantry under fire.

At about the same time 306 Battery from Merton Road Drill Hall fought at the first siege of Tobruk. Two years later the same battery had the honour of being reviewed on the 18th June 1943 in Tripoli by King George VI.

The 305 Battery also saw service in the desert—Benghazi and Tobruk are the resting places of gunners from Tulse Hill. Also, 3 officers and 94 men were caught by the Afrika Korps Panzers on the last retreat eastward in June 1942.

The tide turned for the L.E.E. men who had fought—in addition to Rommel—fierce heat, sandstorms, desert sores, dysentry and long spells of monotony, when, on the 29th September 1942, to a desert searchlight detachment of 390 Battery came a new general with a black beret and two badges—General Montgomery. He was checking that all was well for the final victory to be acclaimed by the world at El Alamein. Here, again, the experimental role in which the London Electrical Engineers had excelled for nearly fifty years was exploited. A battle observer wrote:

'Simultaneously with the barrages two searchlights shot flaming fingers skyward—to me those searchlights were the crowning triumph of the organization which had gone into the battle. With cross bearings the advancing gunners could establish precisely the new positions on their maps, so that the guns could continue to range and so drive the Afrika Korps to its final defeat.'

In 1947 the regiment reformed, and the original headquarters of the four batteries who have always been a South London Territorial Unit were handed back. The regiment moved with the times, welcoming as they came Gunners, the Women's Royal Army Corps, Z Reservists and National Service men, until, with Army reorganization in 1955, the 'Ack Ack' Command was disbanded; with this disappeared the L.E.E. Unit founded by volunteers nearly sixty years ago.

The Secretaries of the Old Comrades' Associations have formed a Committee to organize the dinner, and they intend to make a special endeavour to contact officers, N.C.O.'s and men who have served with the unit.

Members of The Institution are invited to write in the first place to Mr. L. E. G. Pugh, 14 Ribblesdale Road, London, S.W.16 (telephone: Streatham 5219).

HIGH-VOLTAGE CIRCUIT-BREAKERS

From R. A. HORE, M.A., B.SC., ASSOCIATE MEMBER

I should like to draw attention to one aspect of the testing of high-voltage circuit-breakers which is not at present covered by any British Standard on circuit-breakers.

In the design of extra-high-voltage transmission schemes the over-voltages generated within the system, particularly by switching operations, are of major importance in determining the insulation levels of the apparatus. This is because such over-voltages are more or less proportional to the system voltage, whereas the other factor, lightning over-voltage, is more or less independent of system voltage and thus becomes less important as the system voltage increases.

The most common occasions of excessive switching over-voltages are the switching out of unloaded transmission lines and of unloaded transformers. In the latter category we may include the switching of shunt reactors. It is increasingly common practice to test circuit-breakers for these duties to ensure that they do not produce excessive over-voltages.

Probably the most important parameter determining the over-voltage produced by a given breaker on a given circuit is the instant of contact separation measured with respect to current zero. The critical point of separation is, however, generally unknown, and to find it necessitates a thorough search involving many operations with 'point-of-wave' switching. Even when the critical time is found, the resulting over-voltages show some random variations from test to test. Consequently, it is common practice to make a number of tests with random timing.

Since the number of tests made is always limited, it is clear that the maximum over-voltage observed is in general less than the maximum which may eventually be experienced in service. The following analysis is, therefore, concerned with providing a method of assessing the maximum over-voltage which may be produced using as data a limited number of test results.

Distribution of Over-voltage

It is first necessary to decide upon a reasonable distribution of over-voltage, i.e. upon a reasonable form for a curve showing the over-voltage produced plotted against its frequency of occurrence. Granted a large number of tests, this distribution can be determined experimentally, but it is precisely because it is desirable to avoid a large number of tests that this analysis is being undertaken.

It may be shown that, for results of the required order of accuracy, no serious error is likely to be introduced by assuming a normal or Gaussian distribution. On the other hand, such a distribution assumes the possibility of very high over-voltages, and although this possibility is extremely remote the distribution may be considered by some to be unacceptable because of this.

A reasonable alternative is to assume a triangular distribution, which is of the correct general shape and has a definite maximum. In what follows we shall examine the implications of these two distributions.

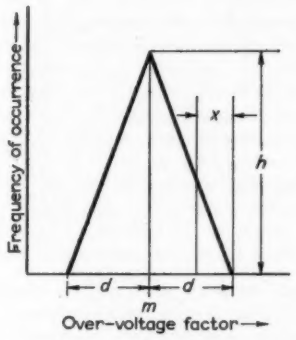
Mr. Hore is with Merz and McLellan.

General Analysis

(i) *Triangular distribution.* This is shown in the diagram.

Consider n single-phase tests, the mean over-voltage being m, the maximum observed over-voltage being $m + (d - x)$. The maximum over-voltage on an infinite number of tests is $m + d$.

Since all possible results lie between $m - d$ and $m + d$, $hd = 1 \cdot 0$. The probability that any single test gives an over-voltage less than $m + (d - x)$ is $\left(hd - \frac{hx^2}{2d}\right)$, i.e. the area to



the left of $m + (d - x)$. Thus the probability that n successive results are all below $m + (d - x)$ is $\left(hd - \frac{hx^2}{2d}\right)^n$.

Since our set of n tests is assumed representative of the breaker behaviour this probability is 0·5, i.e. it is equally likely that in n tests all results are below $m + (d - x)$ as that some are above this value. Expressed another way, it is equally likely that the highest result of n tests lies above or below $m + (d - x)$.

$$\text{Hence } \left(1 - \frac{x^2}{2d^2}\right)^n = 0 \cdot 5, \text{ since } hd = 1 \cdot 0$$

$$\text{or} \qquad x/d = \sqrt{[2(1 - 0 \cdot 5^{1/n})]}$$

Thus, to obtain the maximum possible over-voltage $(m + d)$ we must add to the mean over-voltage a quantity k_1 times the difference between the mean and the maximum observed over-voltage, where

$$k_1 = \frac{d}{d - x} = \frac{1}{1 - \sqrt{[2(1 - 0 \cdot 5^{1/n})]}}$$

The values of k_1 are given in the table below.

(ii) *Normal or Gaussian distribution*

If y is measured from the mean, and if

$$\text{erf } y = \int_{-\infty}^{y} \varepsilon^{-x^2} dx$$

then, following the previous reasoning,

$$(1 - \text{erf } y)^n = 0 \cdot 5$$

$$\text{or} \qquad \text{erf } y = 1 - 0 \cdot 5^{1/n}$$

From tables of the error function we may find y/σ for any erf y given by the above (where σ is the standard deviation of the distribution). Since the probability of exceeding 3σ is roughly 0·1% we may reasonably take this as the maximum over-voltage. A typical calculation is as follows:

For $n = 6$, erf $y = 0{\cdot}1086$. From tables of the error function, $y/\sigma = 1{\cdot}235$. Hence the difference between the mean and maximum observed over-voltage should be increased by a factor $k_2 = 3{\cdot}0/1{\cdot}235 \simeq 2{\cdot}43$. The values of k_2 are given in the table.

Results and Applications

The table shows the factors k_1 and k_2 for various values of n. The application of these factors is as follows:

If the mean over-voltage factor on ten single-phase tests is 2·3 and the maximum over-voltage factor is 2·6, then, with a triangular distribution, the maximum over-voltage factor is equal to $2{\cdot}3 + (0{\cdot}3 \times 1{\cdot}58) = 2{\cdot}78$.

With a normal distribution, the maximum over-voltage factor is equal to $2{\cdot}3 + (0{\cdot}3 \times 2{\cdot}0) = 2{\cdot}90$.

N three-phase tests can reasonably be considered as $3N$ single-phase tests.

Calculated results

n	k_1	k_2
6	1·88	2·43
10	1·58	2·0
18	1·38	1·68
54	1·19	1·35
162	1·10	1·14

Conclusions

The difference between the results obtained by the two different distributions is small, except when very few tests are made. The analysis emphasizes the need for making a reasonable number of tests. It also provides estimates of how many tests are reasonable, and shows how to assess the significance of a limited number of test results.

ENGINEERING MANPOWER

From Mrs. V. T. BROWNLESS, M.A., B.SC.

It is with great interest that I read both the article entitled 'Engineering Manpower' by Dr. E. R. Patrick in the September issue and the Foreword in the October issue of the *Journal*.

In his first paragraph Dr. Patrick states, 'Progress will be dependent on the availability of even more highly trained men and women at the top, middle and especially at the lower levels'. Yet in the third paragraph he writes, 'Consequently, it is the distribution of males—boys and men—which is of prime importance', and the whole of his article deals with the supply and training of males. One of his conclusions is that there is no hope of any real increase in 'the supply of trained men for a decade'. What of the women?

Your Foreword gives a very fair survey of the past and present positions, and of the benefits and drawbacks to the community of having women entering the technical field in large numbers.

I would stress 'in large numbers' for your remark, 'So far there have been no real signs that an appreciable intake of professional women engineers would be welcome in all the appropriate parts of the electrical industry', is well supported by many articles, including two printed in *The Times Educational Supplement* on the 21st and 28th September 1956, on women scientists in industry. Here they also showed that, although women are taking an increasing part, management still tends to underestimate the variety of work which they can do. Your contributor appears to go further and, apart from one brief mention, implies that it is not even worth discussing the supply of women. Does he realize that the Women's Engineering Society held its 34th annual conference last year at Portsmouth?

By all means 'avoid keeping promising boys and men at work below their capabilities'. But we should also avoid keeping promising girls and women out of the engineering field altogether.

Mrs. Brownless is a Senior Research Assistant in the Australian Council for Educational Research.

MACHINE TRANSLATION

From I. S. MUKHIN

In the January issue of the *Journal* Mr. Denis Williams makes several comments on my paper *An Experiment on the Machine Translation of Languages carried out on the BESM.*

The article from *The Times*, given as an illustration of machine translation, was translated by the electronic computer BESM on the 15th February 1956 without any intervention of 'something more human'. And this is important. If the details are to be discussed the following should be mentioned.

This translation was merely experimental, its only aim being the checking of *the grammatical part of the translation programmes* for their application to non-scientific text. The experiment proved successful; no correction to the programmes was found necessary for the translation. Thus it backed our general theory that a set of grammatical rules can be formulated in such a way that one and the same set of 'grammar' programmes may be used, no matter whether an English scientific book or a newspaper article or indeed any piece of writing is to be translated by machine from English into Russian.

The preliminary work required by the experiment consisted in searching the text for the new words to be entered into the machine-translation dictionary. Part of the work was done by the computer itself, which supplied a list of the words from the text that had not been found in our scientific-translation dictionary. Then came the linguists' part of the work; the new words were given their Russian equivalents, but only those that were likely to appear afterwards in a scientific text received careful consideration. As for the new words not belonging to this category, we took no great interest in their particular translation, since it was of no importance either for the experiment or for our future work on scientific machine translation. In order to proceed with the experiment, we gave them Russian equivalents suitable for this or that particular sentence of the text.

Most of the words mentioned by Mr. Denis Williams are the latter type. Small wonder that some of them may have given the impression of being 'unbelievably fine' for mechanical translation 'although . . . not impossible in a free translation'.

The preliminary work done, no editor, whether pre- or post-editor, ever touched the text; the translating was done by the computer.

Should Mr. Denis Williams still find any puzzling points in the translation, would he not care to send me his further comments? I should most willingly answer him.

Dr. I. S. Mukhin is at the Academy of Sciences, U.S.S.R.

RADIO RECEPTION IN INDIA

From F. C. McLEAN, C.B.E., B.SC., MEMBER

The letter from Mr. K. L. Rao in the November 1956 issue contained points of interest to the B.B.C. on which I should like to comment.

It will be remembered that the paper by Humby and Minnis, which Mr. Rao refers to, defines asymmetry as 'a difference between the performance of a circuit in the incoming and outgoing directions', but Mr. Rao's observations refer to two discrete paths and do not, therefore, come within the context of the paper. While it is, of course, possible to make comparison between transmissions over such paths, it is difficult to draw useful conclusions that take due account of all factors. Even assuming similarity of transmitting characteristics, there remain basic differences in propagation conditions such as path length, optimum waveband, ionospheric absorption, ground losses, etc.

Mr. Rao quotes his reception of the B.B.C. and A.B.C., operating simultaneously on the same 31 m channel, but it would be unwise to draw any general conclusion, except from a prolonged series of observations. Conventional theory would, however, indicate that circuit conditions on 31 m around 1600 G.M.T. would favour reception of the A.B.C. transmissions in India for most of the year, as compared with those from the United Kingdom.

I am not by any means clear how Mr. Rao deduces that his observations contradict the inference drawn in the paper by Humby and Minnis regarding the apparent movement of the noise centres: perhaps we shall hear from the authors in reply to this point. Quite apart from any question of asymmetry between the United Kingdom and Australia, the B.B.C. has for a long time been aware of apparently anomalous behaviour along this path. An interesting example occurred recently when the B.B.C. Far Eastern Service relay base near Singapore was used to reinforce the A.B.C.'s broadcasts of the Olympic Games at Melbourne directed towards Europe from their transmitter base at Shepparton. At the Singapore base, we had transmitters of approximately equal power operating for twenty days in the same short-wave band (13 m) from 0700 until 1530 G.M.T., and using aerials of similar performance directed over practically the same great-circle path (Singapore is, of course, about 6000 km nearer London than Shepparton). In these circumstances, it would seem that reception in the United Kingdom of the Singapore relay should have been stronger than the direct signal from Shepparton at a given time. In fact, at the start of transmission around 0700 G.M.T., Singapore was substantially stronger than Shepparton; but from about midday G.M.T. until the end of the simultaneous transmissions at 1530 G.M.T., Shepparton was generally stronger—often by a considerable margin. From the above, it will be apparent that there is a great deal we do not yet fully understand about short-wave propagation via the ionosphere. In conclusion, I should like to say that, at all times, the Engineering Division of the B.B.C. will welcome and reply to reports from any part of the world on reception of its short-wave transmissions.

Mr. McLean is Deputy Chief Engineer of the British Broadcasting Corporation.

OBITUARY

RICHARD JOHN BAYNTUN HIPPISLEY

The death of Richard John Bayntun Hippisley, C.B.E., J.P., D.L., in April 1956, at the age of 90, brought to a close a very remarkable and varied career.

Cmdr. Hippisley was educated at Rugby and at Hammond College (now Faraday House). He was trained as an engineer, and in 1885 started his apprenticeship with the Anglo-American Brush Electric Light Corporation. Towards the end of the term of indentures his grandfather died, and his father having died earlier, Hippisley returned to his ancestral home, Ston Easton Park near Wells in Somerset, one of the comparatively few remaining country houses and landed estates held by the same family for many generations; the original grant of the manor was in the reign of King Edward the First. Never, however, did he lose his intense interest in engineering work, and in the course of many years he established what was probably the finest amateur workshop in the country. As the years passed, Hippisley's interests and responsibilities became wide and varied. Besides being Traffic Commissioner for the Western Area and a County Alderman for Somerset, he entered fully into the communal and sporting life of the neighbourhood. He was a Justice of the Peace and a Lieutenant-Colonel of the North Somerset Yeomanry, and was a good shot and a keen fisherman.

The First World War, however, afforded Hippisley the opening to a place in the roll of fame when he was appointed by the Admiralty a Commander in the R.N.V.R. and given *carte blanche* to select, organize, and maintain, throughout the war, the wireless stations around these islands. It was Hippisley and his colleague, Russell Clarke, who set in motion the naval intelligence system which was not only the greatest single factor that gained the victory at sea, but also altered the course of world history by the skilful handling of intercepted cyphered messages.

Tradition also was satisfied, for his great grandfather, Sir William Henry Bayntun commanded the *Leviathan* at the battle of Trafalgar; his portrait, together with a picture of his ship and the Frenchman during the engagement, is preserved in the library at Ston Easton.

Cmdr. Hippisley was appointed an O.B.E. in 1915, and a C.B.E. in 1937.

In the Second World War he continued his Admiralty work but in a more technical sense, for he became an Admiralty subcontractor. Amongst varied activities for which his unique workshop was well equipped, he produced the prototype wind-direction and wind-speed indicator installation for H.M.S. *Indefatigable*. He also carried out repairs and modifications to the wind and gyrocross indicators in the light aircraft carrier *Attacker*.

Towards the end of his life Cmdr. Hippisley was honoured by a visit from the late Queen Mary. She was very much interested in his workshop, and during tea the beauty of some silver spoons engaged Her Majesty's attention. On inquiry, her host informed her that they were of his own manufacture; later he proceeded to stamp out a spoon for her from the raw silver sheet, and was rewarded with an autographed portrait.

He married Constance Francis, the daughter of the late headmaster of Blundell's School, who died in January 1955, and is survived by two sons and a daughter.

Cmdr. Hippisley joined The Institution as a Member in 1919.

J. H. B. R.

ALFRED BRAWN GILBERT

Alfred Brawn Gilbert, who died on the 16th July 1956, was born on the 24th November 1873. He was educated at King Edward's School, Birmingham, and from 1890 to 1895 received practical training with the National Telephone Co. at Birmingham and Coventry. In 1895 he was made a service inspector, and was promoted in 1896 to Local Manager at Derby. Further rapid promotion followed and he held appointments at Nottingham, Exeter and Glasgow, where he was District Engineer. For some months before the National Telephone Co. was taken over by the Post Office in 1912, he was a Divisional Officer of the company in charge of making an inventory of its equipment prior to its sale. His first appointment with the Post Office was Executive Engineer, at Glasgow, and in 1913 he became Assistant Superintending Engineer in Edinburgh, where he remained until 1929. He was then promoted to Superintending Engineer of the North Midland District, with his office at Nottingham. Mr. Gilbert retired from the Post Office in 1934 under the age limit regulation; he continued to live in Nottingham, although he was a great lover of Edinburgh.

Mr. Gilbert brought great energy to the work he carried out, and he won the loyal co-operation of all those with whom he worked. At a ceremony in Nottingham on the day he retired there were many appreciative tributes paid to him by his colleagues in other Departments and by members of his own staff.

He joined The Institution as an Associate Member in 1912 and was elected a Member in 1922.

FREDERICK ERNEST MITTON

Frederick Ernest Mitton, who died on the 29th February 1956, was born on the 25th February 1873. He was educated at the Whitgift School, Croydon, and after leaving school entered the Central Telegraph Office, where his father was Superintendent. While there he studied the electrical engineering side of telegraphy and telephony at technical institutes, gaining distinction in the City and Guilds examinations for certificates in these subjects.

In 1904, after a short period in Cardiff, he was transferred to the London Engineering District of the Post Office, where he spent the rest of his engineering career. He gained experience in the provision and maintenance of engineering plant of all kinds for telegraph and telephone purposes in different parts of London and at the headquarters of the District, where his contribution to the economic planning of line plant networks was important in the successful building up of the London telephone system.

The outbreak of the First World War in 1914 found him posted to the Centre External Section, which is one of the two most important sections in the London area. It includes the headquarters of the Defence Ministries and many other Government Offices in Whitehall, as well as most of the residential and business parts of the West End. Mr. Mitton was responsible for the provision and maintenance of the plant necessary for the communication requirements of many Government Departments during the war, as well as for those of the general public.

Mr. Mitton remained in the Centre External Section until 1933, when he retired owing to his reaching the age limit. During this period, among other activities, he devoted a good deal of attention, with considerable success, to methods of improving the efficiency of the Engineering Department. Six years prior to his retirement he had been promoted to the rank of Executive Engineer in charge of the area in which he had honourably spent most of his official life.

Outside his official duties he was interested in all branches of electrical engineering, in particular the then young radio industry. For about twelve years he lectured and demonstrated in electrical subjects at evening classes in Croydon.

A keen lover of music, he carried out many experiments designed to improve the accurate reproduction of musical frequencies in loud speakers. Latterly he took an active part in the movement to draw attention to the hardships suffered by Civil Service and other pensioners owing to the rising cost of living.

His domestic life was clouded by the death of his only son shortly after the latter had passed an entrance examination into the Post Office, and by the long illness of his first wife. He removed to Worthing after his retirement and his later years were spent happily with his second wife, who survives him.

Mr. Mitton joined The Institution as an Associate Member in 1911 and was elected a Member in 1921. W. D.

REGINALD CHEYNEY PLOWMAN

With the passing, on the 17th September 1956, of Mr. R. C. Plowman there has gone from our midst a man of outstanding ability and great personal charm who, during a long and active business life, had endeared himself to a wide circle of friends and acquaintances in many parts of the world.

Reginald Cheyney Plowman, or 'R. C. P.' as he was familiarly known by his collegaues, was born in London on the 15th April 1886. He received his early scholastic education at Owens School, and his technical training at Finsbury Technical College under Professor Silvanus P. Thompson. He then served an apprenticeship with the Wallsend Slipway and Engineering Co. Ltd., before taking up appointments with London United Tramways, and Messrs. Tyler and Freeman, electrical contractors.

In 1911 he joined the Foreign Department of A.E.G. in Berlin, and was later on the company's engineering staff in Mexico, being in Mexico City during its bombardment by the Mexicans, and in Vera Cruz during its bombardment by the Americans. The unrest in Mexico caused his recall to Germany in the summer of 1914—a step which proved unfortunate in that it led to his being interned in Ruhleben camp, as a civilian prisoner-of-war, from 1914 to 1918.

During this period of 'restricted movement' Mr. Plowman made good use of his time and entered fully into the various activities of camp life. He was a prominent member of the 'technical circle' which had been formed to keep alive engineering and scientific interests, and gave his support to educational, cultural and other diversions. Like many other internees, he took up the study of languages and added Russian to those with which he was already familiar.

After returning to England, he joined the Export Department of the British Thomson-Houston Co., at Rugby, and he was made responsible for the export business of the company in 1934. On the formation of the B.T.H. Export Company in 1947, Mr. Plowman was appointed Executive Director, and in the same year he visited South Africa and initiated the formation of a subsidiary company.

On retiring, Mr. Plowman, with his wife, travelled extensively, visiting Australia, New Zealand, South Africa, and other parts of the world.

His courtly manner and engaging smile, with his wide knowledge of men and affairs, made Mr. Plowman an ideal manager. He combined firmness with an understanding of the other man's point of view, and he seldom became ruffled in argument or discussion—it was hardly possible to quarrel with R.C.P.! He was a genial host and a good mixer—qualities which contributed not a little to his success as a company executive.

Mr. Plowman leaves behind a widow, a son who follows on the engineering tradition in South Africa, and a daughter who is a radiotherapist in Canada.

He joined The Institution as a Student in 1903, and was elected an Associate Member in 1912 and a Member in 1937. He was Chairman of the London Students' Section 1909–10, and was awarded Student's premiums in 1910 and 1911. J. H. M. N.

JOHN WILFRED RODGER

John Wilfred Rodger, who died on the 16th August 1956, was born at Warrenpoint, Co. Down, on the 3rd July 1887. He was educated in Northern Ireland and at the Technical Schools, Bolton. From 1903 to 1906 he served his apprenticeship with Paterson, Cooper, and Co., Paisley, and completed his early practical training with Royce Ltd., Trafford Park. He continued his engineering education by part-time study at Manchester College of Technology, Woolwich Polytechnic, and Goldsmith's College (University of London). In 1906 he accepted a position with Johnson and Phillips Ltd., and

later there followed appointments with Ferranti Ltd., and the Hackbridge Electric Construction Co.

In 1924 he joined Bruce Peebles and Co., Edinburgh, to introduce and develop the manufacture of transformers in Scotland, an activity which, under his wise guidance, proved eminently successful and for which he will long be remembered and admired. He was appointed Chief Engineer of the company in 1933, a Director in 1941, General Manager in 1943 and Managing Director in 1946. During the last 23 years his outstanding gifts of personality and engineering knowledge were widely applied to the great benefit of all his company's affairs. Keenly appreciative of the importance of exports, Mr. Rodger travelled extensively abroad, and in 1952–53 he undertook with Mrs. Rodger a tour that encircled the world, thus acquiring an intimate knowledge of the practice and requirements of many countries.

His father was Irish, his mother a Scot, and in him the best of the characteristics of these two nations were happily blended; from his father, no doubt, he inherited his gay and gallant nature and his own particular and undoubted charm; it was from his mother perhaps that he derived his traditional solidity and tenacity and also fortitude in adversity throughout a life which was not an easy one. Certain it is that during his career he attracted to himself an exceptionally high measure of affection, respect and admiration. He was a man of wide interests, seeking relaxation in golf, fishing and shooting, but giving unsparingly of his time in many public and other offices, particularly in the field of education and training of young engineers. He was a Past-President of the Scottish Engineering Employers' Association, Vice-President of the Edinburgh Chamber of Commerce, a Member of Council of the British Electrical and Allied Manufacturers' Association, and a Governor of Heriot-Watt College.

He is survived by his second wife and by the two sons of his first marriage.

Mr. Rodger joined The Institution as a Graduate in 1912 and was elected an Associate Member in 1916 and a Member in 1938. He served on the Scottish Centre Committee 1930–33 and again 1943–45. He represented The Institution on the Joint Committee for National Certificates and Diplomas in Electrical Engineering (Scotland) from 1947 until his death. W. B. L.

WILFRID JOHN SULSTON

Wilfrid John Sulston, M.SC., A.INST.P., died on the 1st August 1956 at the tragically early age of 43. He was born on the 12th August 1912, and was educated at Woodhouse Grammar School, Finchley. He graduated in physics with first class honours in 1933 from Queen Mary College, London, where he had been awarded the Neill Arnott Scholarship and Medal in 1932. He obtained an M.Sc. degree in 1935.

Mr. Sulston spent most of his professional life in the Post Office and was among the few who have served on several of the various sides of the telecommunications service. He joined the Post Office in 1934 as an Assistant Traffic Superintendent and in 1935 he entered the Engineering Department by way of the Assistant Engineer competition. In 1949 he became Principal in the Personnel Department, and in 1955 was promoted to Assistant Secretary in charge of the Radio Branch of the Radio and Accommodation Department.

During his service with the Engineering Department, Mr. Sulston was from 1936 to 1939 at the P.O. Research Station, where he worked on dielectric materials and on capacitors suitable for the extended frequency ranges which were then becoming of great interest. At the outbreak of war he was transferred to the P.O. Regional Director's office in Scotland, where he was intimately connected with the provision of circuits for the fighting services engaged in the Battle of the Atlantic. From 1942 to 1944 he was concerned with the design of automatic telephone exchanges, and this work was continued when he transferred to the Signal and Radar Establishment of the Ministry of Supply, to take charge of a development group producing telephone and teleprinter switchboards suitable for general use and for the war in the Far East.

At the end of the war he returned to the P.O. Engineering Department, where he had charge of a group working on the problems of interference with communications arising from neighbouring power systems. In 1949 he joined the Personnel Department, and there among other things he dealt with pensions and the many problems arising from the transfer of Cable and Wireless staff to the Post Office. From 1951 to 1954 he worked in the Engineering Industries Division of the Ministry of Supply, having general responsibility for the heavy electrical engineering industry in connection with import and export licences, development schemes, etc.

When he rejoined the Post Office in 1955 he was concerned with the traffic aspects of exchange design and provision, and later with a wide range of subjects connected with radio. Among these were the introduction of the regulations controlling the radiation from appliances driven by small motors, v.h.f. mobile radio services, and maritime services. He was the leader of the United Kingdom delegation to the Baltic and North Sea Radiotelephone Conference, held at Göteborg in 1955, where important contributions were made to improving short range ship-shore radiotelephone services.

Mr. Sulston was a reserved colleague, but all who had dealings with him, in his department and in industry, respected him for his integrity, and had complete confidence in his judgment. It was characteristic of him to master every detail of his subject, and it came to be expected that his solution of a problem would show expert technical appreciation. He was a devoted husband and father.

He joined The Institution as an Associate Member in 1943 and was elected a Member in 1949. E. F. H. G.

HAROLD CHARLES WELLS

Harold Charles Wells, who died on the 9th September 1956, was born on the 24th March 1888. Educated locally at Hornsey, he started in 1904 with a firm of civil engineers, but left them in 1908 to join the staff of the Mains Department of the County of London Electric Supply Co., thus beginning an association with the supply industry in London lasting 45 years.

In 1913 Mr. Wells was responsible for laying the first distribution mains in Romford, Essex, for which his company had just secured the order. He was appointed in 1923 to supervise the laying of the main underground 33 kV transmission lines feeding into London from Barking power station, which was then under construction. Much of the subsequent development and success of underground transmission at this and higher voltages was due to experience gained in this venture, in which he took an active part.

From 1930 to 1933 Mr. Wells was Assistant Mains Engineer to the company, becoming Mains Engineer in 1933, and responsible for all their distribution work in London, duties which were extended to cover the whole of the associated companies of the County Group in 1939. He held this post until nationalization of the industry. The earlier years of this period were filled with the problems of the development and expansion of urban and rural supplies, the latter with those of the war and its aftermath. Each in turn claimed and received Mr. Wells's attention, as also did the considerable administrative reorganization within the company caused by this expansion.

At Vesting Day, Mr. Wells was appointed one of the two Deputy Chief Engineers to the first Chief Engineer of the London Board, Mr. J. W. Leach, with a special responsibility for the design and planning of the London distribution system, involving the co-ordination of the existing systems of some forty undertakings comprising the Board. On Mr. Leach's retirement in 1949, Mr. Wells became Engineering Adviser to the new Chief Engineer, Mr. D. B. Irving, the present Chairman of the London Board, and took an active part in all schemes for the development of distribution in London until his retirement in 1953.

He was a man of considerable ability, great industry and drive, loyal to his staff, many of whom he helped, and a good friend and companion. He is survived by a widow and one son.

Mr. Wells joined The Institution as a Graduate in 1920, and was elected an Associate in 1929, an Associate Member in 1935 and a Member in 1941. He was also a member of the Société des Ingénieurs Civils de France. G. J. M.

MONOGRAPHS AND PAPERS
published individually this month

Synopses of monographs and papers published individually before the next issue of the Journal are given below, and, unless otherwise stated, their dates of publication are this month. Reprints of all papers are available about two months after publication in the Proceedings. The prices shown below are post free. When ordering please quote serial number of paper or monograph. Books of 8 vouchers may be obtained from the Secretary, price 10s. each.

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MONOGRAPHS

Theory and Equivalent Circuits of the Stator-Fed Polyphase Shunt Commutator Motor

MONOGRAPH No. 220 U

C. S. JHA, B.Sc.

Tensor analysis is used to develop a comprehensive theory of the stator-fed 3-phase shunt commutator motor. Before proceeding with the general analysis, the simple machine where all the phase shift between the secondary standstill induced voltage and the secondary impressed voltage is either in the motor or the regulator is considered. From the equations of performance of the simple machine, the existing equivalent circuit proposed by Coulthard is derived. The limitations of this circuit are discussed and better circuits are proposed. For the general analysis the machine has an auxiliary winding on the stator displaced from the main winding for power-factor improvement, a shift of the brushes from the neutral position, and a biased double regulator with completely dissimilar-component single regulators for speed and power-factor control.

The Conductivity of Oxide Cathodes: Part 1—Potential Distribution

MONOGRAPH No. 221 R

G. H. METSON, M.C., Ph.D., M.Sc., B.Sc.(Eng.)

The monograph is the first of a series dealing experimentally with various aspects of the conductivity of oxide cathodes. It starts with a brief survey of existing knowledge and then proceeds to examine the practical circumstances under which a non-uniformity of potential gradient can arise across the matrix under a modest continuous current loading. By using active-nickel cores to enclose a rectangular slab of barium-strontium oxide, it is found by probe experiments that non-uniformity of potential gradient occurs only in the presence of residual gas, and that the gradient tends to increase in those parts of the matrix likely to accumulate negative ions.

Simulation of the Transient Performance of Synchronous Machines on an A.C. Network Analyser

MONOGRAPH No. 222 S

COLIN ADAMSON, M.Sc.(Eng.), and A. M. S. EL-SERAFI, B.Sc., Ph.D.

In order to make further progress with the solution of multi-machine transient problems, it is necessary to augment the facilities of network analysers, the most convenient of the analytical tools available to the power-system engineer. The paper describes a new simulator which enables the symmetrical a.c. transient component of current or voltage of a synchronous machine, subsequent to any 3-phase disturbance, to be obtained. The simulator is based on the duals of equivalent circuits for the direct and quadrature axes of synchronous machines, and is entirely electronic in its operation.

Experimental results are given and a comparison is drawn between these and the results obtained by calculation. It is concluded that such a simulator is an essential preliminary step towards a more accurate representation of machines and their associated apparatus, either individually or when interconnected in a power system.

An Experimental Investigation of Tooth-Ripple Flux Pulsations in Smooth Laminated Pole-Shoes

MONOGRAPH No. 223 S

PROFESSOR J. GREIG and K. C. MUKHERJI

The monograph describes certain experiments designed to investigate the mode of penetration of tooth-ripple flux pulsations in smooth laminated pole-shoes. Simple measurements made by means of search coils embedded in holes drilled axially at different radial depths from the pole-face have revealed a mode of radial penetration in the quasi-stationary state which is similar to the theoretically derived static mode. Measurements have been made with different materials at a range of tooth-ripple frequencies and with different sizes of holes. The results provide substantial evidence in support of an analysis of tooth-ripple phenomena contained in a companion paper.

An Analysis of Tooth-Ripple Phenomena in Smooth Laminated Pole-Shoes

MONOGRAPH No. 225 S

PROFESSOR H. BONDI and K. C. MUKHERJI

Classical linear electromagnetic theory is used to investigate the mode of penetration of tooth-ripple flux into smooth laminated pole-shoes, without making any assumption as to the thickness of the laminations employed. It is shown that, apart from the mode corresponding to the classical 'depth of penetration' concept, there also exists a completely different mode which penetrates to a much larger radial depth, but has a non-uniform distribution across the thickness of the laminations, with the maximum values occurring at the interfaces.

With thicknesses usually employed in practice, at least 60% of tooth-ripple eddy-current loss is found to arise from this latter mode of penetration so that only a fraction of the total loss could properly be called a 'pole-face loss'. The work was carried out at King's College, University of London.

Propagation of Transients in Waveguides

MONOGRAPH No. 224 R

A. E. KARBOWIAK, Ph.D.

The basic theory of transient propagation in waveguides is formulated and developed. The theory is subsequently applied to the propagation of a unit-step-modulated carrier and the propagation of pulses. Formulae and graphs are outlined for various transients involved and pulse distortion is studied in detail. The results are illustrated by numerical examples.

Discriminator Distortion in F.M. Systems

MONOGRAPH No. 226 R

R. G. MEDHURST, B.Sc., and H. D. HYAMSON, B.E.E.

In a previous paper expressions were obtained for the distortion of the modulation when an f.m. wave passes through a network whose group-delay and amplitude characteristics both exhibit small departures from constancy. An ideal discriminator network has the property that when it is fed with an f.m. wave the amplitude modulation of the output is an exact copy (except for a scale factor) of the frequency modulation of the input. This can be achieved by a network whose group-delay characteristic is constant and whose amplitude characteristic is linear. In the present monograph the theory given previously is extended to cover discriminator networks whose characteristics exhibit small departures from these ideal forms. Single-tone and noise-band modulations are considered. Two numerical examples are given, one being a design of 2-tuned-circuit discriminator, which is considered in relation to a 240-channel f.d.m. telephony system, and the other is an improved balanced discriminator suitable for a 600-channel system.

PAPERS

Engineering Education in the Soviet Union

PAPER No. 2308: PART A

This report is presented to the Councils of the Institutions of Civil Engineers, Mechanical Engineers and Electrical Engineers, to the Minister of Education and to the British Council by the team of engineers who visited Russia in September 1956.

When the Soviet Relations Committee of the British Council first formulated their policy of arranging with the Soviet Government for an exchange of teams of experts, it was natural that engineering should be one of the subjects considered. The Committee approached the Councils of the three Institutions, who, in view of the known remarkable developments in higher technological education in the Soviet Union, proposed exchange visits on these subjects, and both Governments readily accepted the suggestion. The British team left this country by air on the 16th September 1956, and returned on the 28th September. The return visit of eight directors and professors from higher technological institutes in the Soviet Union took place in the following month.

To be read on the 25th February

Mechanical Strength of Power Transformers in Service

PAPER No. 2317 S: PART A

E. T. NORRIS

The mechanical stresses in power transformers have steadily increased with transformer size and supply-system capacity. Short-circuit currents are generally based on the rupturing capacity of circuit-breakers, which has increased in 25 years from 1 500MVA to 25 000MVA.

The position has been accentuated in recent years by the established practice of auto-reclosing, which makes repeated switching on to possible faults a normal practice, and the introduction of fault throwing for inter-tripping purposes, where dead short-circuits are deliberately created under normally controlled conditions.

Using only simple mathematics, the author shows that the mechanical strength of a transformer is not a simple single value as is implied in the short-circuit clauses of standard transformer specifications. Some of the strains are progressive, and some of the stresses cumulative, leading to short-term and long-term characteristics. The resulting categories of mechanical strength are defined as initial critical and ultimate, the last named being usually the crucial one.

It is shown how the performance in service can be predetermined and the expectation of life, in terms of number of short-circuits, predicted for any given operating conditions. Service records of failures on short-circuits are analysed and found to support the predicted values.

To be read on the 27th February.

D.C. Winder Drives using Mercury-Arc Rectifier/Inverters

PAPER No. 2324 U: PART A

L. ABRAM, B.Sc.(Eng.), J. P. McBREEN and J. SHERLOCK, B.Sc.(Eng.)

The high efficiency of mercury-arc rectifier equipments would appear to make their use desirable on winder drives, on which efforts are continually being made to reduce hoisting costs. After outlining the requirements of a winding engine, the paper briefly describes a.c. and d.c. Ward Leonard drives and discusses their advantages and disadvantages. A comparison is made between these drives and a rectifier drive. The advantages of the latter led to the installation of one at Monk Bretton No. 3 Shaft, and the various rectifier connections and the methods of changing from rectification to inversion there are considered. Various aspects of grid control and transformer design are discussed, and some rectifier faults are described, as well as the protection provided against them. A comprehensive series of these was carried out on the installation, and the results obtained are illustrated.

Date for reading not yet fixed

The Stereosonic Recording and Reproducing System (A Two Channel System for Domestic Tape Records)

PAPER No. 2332: PART B

H. A. M. CLARK, B.Sc.(Eng.), G. F. DUTTON, Ph.D., and P. B. VANDERLYN

The paper reviews briefly the history of stereophonic reproduction. The principal basic systems with their underlying ideas are described and compared. Some account is given of the supposed mechanism of natural binaural listening from the viewpoint of directional localization.

The aims of the 'stereosonic' system for domestic use are defined, and the mathematical theory involved in its use developed. Limitations and sources of error in the results achieved are described. Equipment used in the making of master recordings and some of the problems of studio technique involved are described. Consideration is given to the form which a domestic 'stereosonic' record should take, and the standards to which such a record should conform, together with the requirements which these impose on the reproducing equipment.

To be read on the 20th February

Cathodic Protection

PAPER NO. 2336: PART A

L. B. HOBGEN, O.B.E., M.I.Mech.E., K. A. SPENCE, B.Sc.Tech., and P. W. HESELGRAVE, B.Sc.

The paper deals with the theory and practice of the method of corrosion mitigation known as cathodic protection. The nature of electrochemical corrosion and the fundamentals of cathodic protection are briefly discussed. Then follows a survey of the two practical methods of achieving cathodic protection—sacrificial anodes and power-impressed currents. Since the method of measuring potentials is not that of normal electrical practice, this subject is considered in some detail together with the method of measuring soil resistivity. The possibility of adversely affecting other buried services is noted, and present practice in carrying out potential tests with the owners of such services, and of bonding to eliminate adverse effects is considered. Finally the application of cathodic protection and the general economics affecting its use are discussed.

To be read on the 7th March

An Analogue Computer for Nuclear Power Studies

PAPER NO. 2337 M: PART B

G. J. R. MACLUSKY, B.Sc.

The paper will be published on the 4th March

The paper describes a new analogue computer which has been constructed at the A.E.R.E., Harwell. It is to be used for nuclear power studies and comprises three main sections, namely (i) the reactor kinetics section; (ii) the control system section; and (iii) the thermal system section. The design of these sections and their interconnection is described in detail and brief reference is made to some of the problems which will be studied with this new computer.

To be read on the 12th March

The Application of Analogue Methods to Compute and Predict Xenon Poisoning in a High-Flux Nuclear Reactor

PAPER NO. 2338 M: PART B

G. J. R. MACLUSKY, B.Sc.

The paper will be published on the 4th March

The process of xenon poisoning, and its relation to the operation of a high-flux nuclear reactor, are discussed. An analogue computer which gives the present value of xenon poisoning, and an associated predictor which can be used to plan future reactor operations, are described. This computer/predictor is to be used as a reactor operator's tool.

To be read on the 12th March

Electrical Equipment for Rectifier Locomotives

PART NO. 2339 U: PART A

H. B. CALVERLEY, B.Sc.(Eng.), E. A. JARVIS, B.Sc.(Eng.), and E. WILLIAMS, B.Sc.(Eng.)

The paper will be published on the 4th March

The single-phase 50 c/s system of railway electrification has developed extremely rapidly, and been adopted in recent years by France, Turkey, Portugal, the Belgian Congo and Great Britain. Of the many types of locomotives possible, the rectifier type is at present becoming more and more widely favoured. This is due to its combining the best possible traction motor with the lightest form of converter.

The paper discusses the various types of circuits which have been, or could be used on rectifier locomotives, including h.v. and l.v. control systems, different types of on-load tap-changing circuits, buck-boost control systems, stepless control systems, bridge and bi-phase rectifier circuits, and motors connected in different ways. Different types of tap-changer, transformer and rectifier are discussed. The operation of the motor on current with ripples is compared with d.c. operation, and the many factors which influence the choice of the ripple current are analysed. The principal aim of the paper is to bring together the characteristics of transformers, tap-changers, rectifiers and motors and discuss the advantages and disadvantages of the various ways in which these items can be put together to form a complete equipment.

To be read on the 14th March

Circuit Calculations for Rectifier Locomotives and Motor Coaches

PAPER NO. 2340 U: PART A

T. E. CALVERLEY, B.Sc.(Eng), and D. G. TAYLOR, B.Sc.(Eng.)

The paper will be published on the 4th March

The increasing use of rectifier-type locomotives and motor-coaches has focused attention on the limitations of accepted rectifier theory in the calculation of performance of single-phase/bi-phase and single-phase/bridge-connected rectifier circuits. Most industrial rectifier installations exceeding a few kilowatts in rating are supplied from a 3-phase system, and are designed to operate with 6- or 12-phase output on the d.c. side, while sometimes in very large installations it is necessary to operate with an output of up to 72 phases. In these conventional multi-phase equipments the ripple current is superimposed on the output direct current, but is sufficiently small to permit, for the purpose of calculation, the assumption of a d.c. circuit of infinite inductance. This assumption leads to considerable simplification of the theory. Unfortunately it is not tenable in the circuits discussed in this paper, since the presence of the ripple current in the d.c. circuit has a profound effect on the operation of the whole equipment.

This paper outlines the calculations for bi-phase and bridge circuits, based on the accepted 'infinite inductance' theory, and derives the direct voltage at the motor, ripple current in the motor circuit, power factor in the a.c. supply, harmonic currents in the a.c. supply and other related quantities. A description follows of a new approach to both transient and steady-state problems. The problems are treated as circuit problems, the equilibrium equations being established in terms of mesh currents and expressed as simultaneous first-order differential equations. These are solved by means of an electronic computer.

To be read on the 14th March

TECHNICAL PUBLICATIONS

BRITISH STANDARDS

Copies of the following publications can be obtained from the British Standards Institution, 2 Park Street, London, W.1. The prices given are post free.

B.S. 223: 1956 **High Voltage Bushings** 7s. 6D.

This Standard, which supersedes the 1931 edition, now applies to bushings for indoor and outdoor use on 3-phase systems with rated voltages in the range 3·3–275 kV. It is intended to cover only bushings which can be tested separately without affecting their electrical performance, and, although it can apply to bushings in cable boxes, cable sealing ends are excluded.

Major changes have been made throughout the specification, in particular to the sections dealing with rating and testing. The system of rating numbers used in the 1931 edition has been discontinued, and standard bushings are now rated in terms of service voltage, nominal current, frequency and insulation level. The section dealing with tests has been extensively altered to bring it into line with present practice. Two impulse-voltage tests have now been introduced. There are some useful appendices.

B.S. 530: 1948 **Graphical Symbols for Telecommunications.** Supplement No. 4: 1956, Miscellaneous Recommendations and Symbols (Including Transistors). 3s. 6D.

While B.S. 530 was being revised, an inter-Service list of symbols was issued, which differed from those in the Standard. Later, the Services agreed to use B.S. 530 (and its Supplements) together with an addendum listing these differences. Supplement No. 4 has been drafted with a view to removing these differences, and it will now be possible for the Services to reduce the size of their addendum substantially.

The Supplement contains guiding principles for the preparation of circuit diagrams which are additional to those on pages 5–15 of B.S. 530, and new or modified symbols which reflect advances in technique. Symbols for transistors and allied devices, keeping pace with recent advances in semi-conductors, form an important part of the Supplement. In drafting these, attention has been paid to American practice.

B.S. 2769: 1956 **Portable Electric Tools (Hand-Held)** 3s. 6D.

For some years past portable electric tools have been finding increasing uses for production work, while specialized tools have been developed for the building and other trades. An increasing market has also been created by the domestic amateur. Because of this diversity of application and in the interests of safety it seemed desirable to lay down some standard of construction.

Attention has been given not only to mechanical and electrical features but to such matters as the method of connection to the source of supply and the application of the appropriate protective gear.

The Standard is confined to apparatus operating at a maximum of 250 volts, this upper limit having been selected in the belief that the normal 3-phase supply at 440 volts, or 415 volts, is unsuitable for this type of tool.

B.S. 2791: 1956 **Aluminium Conductors in Insulated Cables** 3s.

This new Standard results from the increasing use of aluminium conductors in insulated electric cables. It provides a standard range of aluminium conductors suitable for use as alternatives to the copper conductors specified in B.S. 7, B.S. 480 and other Standards. The conductor sizes and strand formations given are closely related to the existing copper sizes and have been chosen to meet the major needs of users.

E.R.A. REPORTS

Copies of the undermentioned E.R.A. Reports can be obtained from the British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. The price of each report is given, and, unless otherwise stated, the cost of postage on a report is 4d.

C/T114 **An Experimental Study of Wind Structure** (with reference to the design and operation of wind-driven generators) by M. P. Wax. 21s. (POSTAGE 6D.)

With anemometers specially designed for the purpose, studies have been made of the wind structure at a well-exposed site on a hill. Different methods of defining the gustiness of the wind are discussed. In the analysis of the wind records particular attention has been paid to their application to the problems of wind-power generation. The instruments are described, and some details are given of tests on the response time of different types of anemometer.

G/XT87 **Gas Pressures Produced by an Arc in Contact with Urea Formaldehyde in a Closed Arcing Chamber** by A. E. Helden and W. F. M. Dunn. 7s. 6D.

The problem of arc extinction by gases produced by the action of the arc on solid substances is now coming to the fore, and this report covers preliminary work on the subject. It deals only with pressures produced by gases from urea formaldehyde and not with arc extinction, which will form the subject of a later report.

G/XT91 **Gas Production and Erosion of Material by Arcs in Fibre Tubes** by L. Gosland and W. F. M. Dunne. 21s. (POSTAGE 6D.)

In Report G/XT87 preliminary work on the problem of arc extinction by gases produced by the arc from solids was described. The present report contains data on the amount of material eroded and the gases evolved from fibre by arcs; a formula connecting mass eroded with values of arc length, duration, current, and diameter of tube is included.

G/XT94 **Experiments on a 'Hard Gas' Switch at Relatively Small Currents. Preliminary Report** by L. Gosland. 18s. (POSTAGE 6D.)

In this report preliminary experiments on a simple form of self-blast 'hard gas' switch are described, with particular reference to improvement of performance at the lower end of the current range, mainly by modification of structural factors. Earlier work on the 'hard gas' switch problem has been reported in Reports G/XT87 and G/XT91.

L/T323 Theory of Linear Systems I by B. Gross. 10s. 6D.
The report summarizes part of the results of work on the structure of linear systems, which is being carried out in a joint programme of research by B. Gross and H. Pelzer. The theory is based on the Cauchy-Courant theorem on the boundary values of analytic functions. A new calculus is developed that permits a satisfactory treatment of delta functions and certain divergent integrals.

T/T51 Further Researches on the Phenomenon of Debris Formed in a Meter-Type Bearing with Special Reference to Osmium–Rhodium/Sapphire and Diamond Combinations by G. F. Shotter. 7s. 6D.
An investigation has been carried out on pivots of osmium–rhodium in sapphire and diamond jewels. Tests with various speeds and weights have given some interesting results about the debris formed.

ECONOMIC COMMISSION FOR EUROPE

Annual Bulletin of Electric Energy Statistics for Europe. 1s. 9D.

The first 'Annual Bulletin of Electrical Energy Statistics for Europe' has recently been published. It contains final data, relating to 25 countries, for 1938 and for 1950–54, with provisional data for 1955. The tables given show figures for the maximum net capacity in continuous operation; fuel consumption; international exchanges of electrical energy; production and gross consumption of electrical energy; and average efficiency of thermal plants. All the data contained in the Bulletin have been supplied directly by the governments concerned.

The publication is obtainable from the Sales Section, European Office, United Nations, Geneva, Switzerland.

SOME RECENT BOOKS

A. T. DOVER, F. T. CHAPMAN and others
ELECTRICAL ENGINEERING (GENERAL)
LONGMANS, GREEN. 498 PP. £2 10S.

This book is one of an 'Electrical Engineering Series' for universities and colleges, and in general for students beyond the Ordinary National Certificate level. It is also intended for Servicemen, to provide a basis for the study of their electrical equipment. Four authors are named on the title-page, and the editor, Dr. F. T. Chapman, has had the guidance of a Services Joint Advisory Committee. There have been several authoritative fingers in this pie.

Any addition to the already considerable range of textbooks in this field is subject to scrutiny partly of its scope, even more of its modernity and presentation. This book scores notably in the latter, although in the former its parenthetic 'General' might have more fittingly been replaced by 'Particular'. Its stated subjects are circuits, instruments and measurements, electric and magnetic fields, conductors, insulating and magnetic materials, and electronic tubes. The treatment is confined to direct current and power frequencies.

There is nothing new on conducting and insulating materials or in the discussion of the electric field, but there is an excellent and comprehensive exposition in simple language of modern views on ferromagnetism by Professor Brailsford: this, perhaps, is the best thing in the book, and it is certainly unique in textbooks of this class.

A feature of the layout is good paragraphing, and the typography is pleasing. The line diagrams are in most cases expertly done, with only occasional lapses. (Fig. 6.40, which shows the outside of a synchroscope and gives nothing away about its internals, must have had at least fifty years of active and useless life.)

A team of writers can produce an authoritative text: but there are dangers. Thus network theorems appear under d.c. circuit theory in spite of their more general application. Two of them are repeated—quite unnecessarily—for a.c. circuits. The author concerned has not noticed that what he calls the 'conjugate' of the Helmholtz–Thévenin theorem is in fact the Norton, the Millman and the parallel-generator theorem all in one. The fluxmeter makes a double appearance with different symbols.

There are the few inevitable errors (one is that the quadripole parameters A, B, C, D, are related by the expression $AD - BC = 1$ only when the quadripole is symmetrical), some looseness, some obscurity, and some surprising omissions (such as complex power). The general impression, however, is very favourable. The engineer beyond the state of pupilage may find the book easy and helpful. The student undoubtedly will.

A. DRAPER
ELECTRICAL MACHINES
LONGMANS, GREEN. 362 PP. £2.

This is a second book in the 'Electrical Engineering Series', edited by Dr. F. T. Chapman. It deals with the principles of electrical machines up to the standard required by students working for the Higher National Certificate in heavy-current electrical engineering. The customary syllabus of an engineering degree course is largely covered, but the text lacks the detailed treatment that many degree students might prefer. Based obviously on teaching experience, the book presents its information in an easily assimilated manner that will appeal to students. The needs of people who can devote only part of their time to study are borne in mind, and this has resulted in a clear, direct, and sometimes a little oversimplified, style.

The wide range of subjects covered includes modern topics, such as saturable reactors and magnetic amplifiers; cross-field generators are also discussed, albeit all too briefly. Single-phase motors, which some examinations require, are not mentioned. The use of mathematics is limited to that which the student might reasonably be expected to know.

The treatment of a.c. machines is based on their equivalent circuits, and this leads quickly to equations for their characteristics, and to the development of circle diagrams. In this way the circle diagrams are obtained for induction motors, the shunt-wound three-phase commutator motor, and the Schrage motor. The theory of transformers includes parallel operation, insulation and impulse phenomena. In addition,

illustrated notes on types of transformer and their construction are given.

When dealing with synchronous machines, the author explains the Potier method for round rotors and the two-axis analysis for salient-pole rotors. More detail would have benefited the latter, and in particular enhanced the value of the illustrative example. In this problem, the data include the value of unit quadrature reactance as 0·5 whilst the solution seems to use 0·05. Parallel operation of synchronous machines is clearly explained, and the discussion of the oscillations of a machine on infinite busbars refers to a.c. circuit theory for the solution of the differential equations.

Design parameters, armature reaction and machine characteristics are all dealt with in the chapter on d.c. machines. The descriptive approach to commutation, which seems to be the popular one at the present time, is used. Although the reader may be left with the impression that commutation is less of a problem than it in fact is, nevertheless a good basis for further study is presented.

There are omissions in the book, e.g. in the appendix discussing heating and cooling no mention of hydrogen is made, although a quarter of a century of use has surely established it as standard for large turbo-generators and synchronous condensers. It is essentially a student's book, as the twenty-six pages of questions taken from examination papers bear witness. Moreover, courses in machine technology could, and probably will, be usefully based on it.

D. H. FISHER

V.H.F. TELEVISION TUNERS

HEYWOOD. 143 PP. 21S.

The beginning of commercial television created a demand for domestic receivers capable of working at frequencies much higher than the customary frequencies. With few stations at first, many users were at the extreme edge of the service area. In the design of suitable receivers, therefore, much attention was given to the reduction of avoidable noise and interference; selectivity and the rejection of a more powerful station had also to be considered. The simple input stages of the early television receiver thus developed into the v.h.f. tuner.

This book collects together the information now available on this subject. Some of it was previously to be found scattered in the technical literature, and much has been drawn from Mr. Fisher's own experience. The first section, dealing with design, considers the requirements of a satisfactory tuner for use in unskilled hands; separate chapters then deal with the signal amplifier, the frequency convertor, and the oscillator. Most space is given to the signal amplifier, with special emphasis on noise. The second section deals with the construction of the two types of tuner built around the wafer switch or the turret-coil assembly, and the final section gives advice upon the choice and use of testing equipment.

The treatment is that of a general survey, and seeks to avoid 'the complexity of the textbook'. The student will therefore find that considerable previous knowledge is assumed, and that the precision of the textbook is lacking. The professional reader, wishing to pursue some topics in greater detail, would have found the book more valuable had more references been provided to other work—the three given are quite inadequate. Some diagrams might then have been omitted.

The test methods suggested in the third section are of interest since they come of personal experience; but reliable results depend as much on experimental technique as upon good apparatus, and sweep generators are deceptively easy to use.

G. A. WEDGE

THE ECONOMICS OF ELECTRICAL INSTALLATION DESIGN

PITMAN. 320 PP. £2 5S.

The need for careful consideration of comparative costs of alternative designs and layouts in electrical installation work should need no emphasis to-day. As there seems to be a dearth of published information on this subject, the production of this book is opportune. The author approaches this subject from the point of view of the installation engineer, and discusses the general considerations and the constructional details which affect the economic design of many commercial and industrial types of installation.

An interesting table is given showing the estimated life of various types of wiring and cable distribution, together with corresponding annual maintenance costs and residual values expressed as a percentage of initial costs. Subjects covered include earthing, diversity, power factor, lighting, switchgear, motors and motor circuits, heating, substations, building sites and exhibitions. Throughout the book numerous tables are inserted showing the relative costs of various sizes or alternative types of equipment, expressed as percentages above that which is lowest in first cost. While these afford a useful introduction to this important subject, the author rightly points out that every individual case must be treated upon its own merits.

The author's attention is apt to wander from the main subject of economics to details of good installation practice, and a considerable amount of technical data is included, with numerous charts and tables. Unfortunately, because the technical treatment is not always complete it could be misleading, and errors occur in some of the equations, such as those in the busbar calculations on pages 32 and 33. References to The Institution's Wiring Regulations sometimes relate to the 12th and at others to the 13th Edition; in particular, the section dealing with cable ratings is based upon the 12th Edition. In general the book lacks cohesion and its preparation appears slipshod, with too much information culled direct from manufacturers' publications.

No attempt is made to deal with such matters as the economics of using earthed concentric wiring in buildings supplied by individual substations, or with the relative economy of high- or medium-voltage distribution in large industrial premises. Within the scope covered, however, the practical advice given is sound and the book may well provide a useful introduction to the more general aspects of this important subject.

DISC BRAKES FOR RAILWAY COACHES

British Railways are intending to carry out full-service trials in the Southern Region with a ten-coach electric train fitted with disc brakes similar in principle to those on racing cars.

The use of disc brakes for railway vehicles is a departure from current practice in Great Britain. The disc brake is operated by the normal air-brake control through a brake cylinder controlling a pair of calliper levers having non-metallic thrust pads on the inner ends, which in turn grip the side surfaces of a disc mounted on the axle behind the bogie wheels.

Forthcoming Events at Savoy Place

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E EDUCATION DISCUSSION CIRCLE
I INFORMAL
M MEASUREMENT AND CONTROL SECTION
O ORDINARY
R RADIO AND TELECOMMUNICATION SECTION
S SUPPLY SECTION
U UTILIZATION SECTION

Synopses of all papers to be read in February and March, and particulars of ordering them, will be found on pp. 114–116 under 'Monographs and Papers published individually this month'. A paper that has not yet been published will be available at least ten days before the meeting at which it will be read.

February 1957

I **18** *Monday* DENIS TAYLOR, M.SC., PH.D., will open a discussion on 'The Impact of Radioactive Isotopes on the Utilization Field'*

R **20** *Wednesday* H. A. M. CLARK, B.SC.(ENG.), G. F. DUTTON, PH.D., *and* P. B. VANDERLYN 'The Stereosonic Recording and Reproducing System (A Two-Channel System for Domestic Tape Records)' (Paper No. 2332 R) (At Northampton Polytechnic, St. John Street, E.C.1.)

25 *Monday* Discussion on the Report on Engineering Education in the Soviet Union. Copies of the Report can be obtained from The Institution. (Joint Meeting with The Institutions of Civil and of Mechanical Engineers at The Institution of Civil Engineers, Great George Street, S.W.1.)

M **26** *Tuesday* A. COOPER, B.SC., *and* D. A. DREW, B.SC., will open a discussion on 'The Analysis of Waveforms'†

S **27** *Wednesday* E. T. NORRIS 'Mechanical Strength of Power Transformers in Service' (Paper No. 2317 S)

28 *Thursday* Annual Dinner (At Grosvenor House, Park Lane, W.1, at 7 for 7.30 p.m.) See p. 125.

March 1957

R **4** *Monday* Informal Evening on 'Electronics in Administration—A Survey'. Talk by D. C. ESPLEY, O.B.E., D.ENG.†

S **5** *Tuesday* Supply Section Dinner-Dance (At the Criterion, at 7 for 7.30 p.m.)

O **7** *Thursday* L. B. HOBGEN, O.B.E., K. A. SPENCER, B.SC.TECH., *and* P. W. HESELGRAVE, B.SC. 'Cathodic Protection' (Paper No. 2336)

E **11** *Monday* PROFESSOR A. TUSTIN, M.SC., will open a discussion on 'Simple Approaches to the Understanding of Commutation'* (At 6 p.m., tea at 5.30 p.m.)

MS **12** *Tuesday* (In conjunction with The British Nuclear Energy Conference) G. J. R. MACLUSKY, B.SC. 'An Analogue Computer for Nuclear Power Studies' (Paper No. 2337 M). 'The Application of Analogue Methods to Compute and Predict Xenon Poisoning in a High-Flux Nuclear Reactor' (Paper No. 2338 M)

US **14** *Thursday* H. B. CALVERLEY, B.SC.(ENG.), E. A. K. JARVIS, B.SC.(ENG.), *and* E. WILLIAMS, B.SC.(ENG.) 'Electrical Equipment for Rectifier Locomotives' (Paper No. 2339 U)
T. E. CALVERLEY, B.SC.(ENG.), *and* D. G. TAYLOR, B.SC.(ENG.) 'Circuit Calculations for Rectifier Locomotives and Motor Coaches' (Paper No. 2340 U)

RM **15** *Friday* Radio and Measurement Sections Joint Dinner-Dance (At the Café Royal, at 7 for 7.30 p.m.)

I **18** *Monday* C. RYDER will open a discussion on 'What is Limiting the Application of Servo Mechanisms in the Electrical Industry?'*

R **20** *Wednesday* V. E. COSSLETT, M.A., PH.D., *and* C. W. OATLEY, O.B.E., M.A., M.SC. Lecture on 'Recent Developments in X-Ray and Electron Microscopy with some Applications to Radio and Electronics'‡

O **21** *Thursday* J. W. GALLOP, B.SC.(ENG.), D. D. VONBERG, B.SC.(ENG.), R. J. POST, W. B. POWELL, M.A., J. SHARP, B.SC.(ENG.), *and* P. J. WATERTON, B.SC.(ENG.) 'A Cyclotron for Medical Research' (Paper No. 2342 M)

MR **26** *Tuesday* K. KANDIAH, M.A., *and* G. B. B. CHAPLIN, M.SC., PH.D., will open a discussion on 'The Performance of D.C. Amplifiers with special reference to the use of Transistors'†

S **27** *Wednesday* J. D. HUMPHRIES, B.SC.(ENG.) 'Earth Electrode Systems for Large Electric Stations' (Paper No. 2341 S)

* No advance information will be available and no Press report will be permitted.
† An abstract of the introduction will be available in advance.
‡ No advance information will be available.

District Meetings

Arrangements for District Meetings in March other than those in the area of a Local Centre.

March MAIDSTONE (At the Medway College of Technology, Maidstone Road, Chatham, at 6.30 for 7 p.m.)

4 *Monday* R. W. ROBINSON 'A Description of a Medium Sized Electrical Distribution System with particular reference to Efforts made to reduce Energy Costs'*

OXFORD (At the Southern Electricity Board, 37 George Street, Oxford, at 7 p.m.)

13 *Wednesday* D. WADLAND 'Impulse Testing of Electrical Equipment for Supply Systems'*

READING (At the George Hotel, King Street, Reading, at 7.15 p.m.)

18 *Monday* R. J. HALSEY, C.M.G., B.SC.(ENG.) 'The Transatlantic Telephone Cable'*

* No advance information will be available.

Contents of the Current Issues of the *Proceedings*

DATE OF JOURNAL REVIEW OR SPECIAL ARTICLE	
	PART A. POWER ENGINEERING (FEBRUARY 1957)
January 1957	SIR GORDON RADLEY, K.C.B., C.B.E., PH.D.(ENG.) **Inaugural Address**
January 1957	P. J. RYLE, B.SC.(ENG.) **Supply Section: Chairman's Address**
January 1957	H. J. GIBSON, B.SC. **Utilization Section: Chairman's Address**
	Branch, Centre and Sub-Centre Chairmen's Addresses
February 1957	R. L. HEARN, B.A.SC., D.ENG. **The New Sir Adam Beck Generating Station at Niagara** (PAPER NO. 2204 S)
February 1957	L. R. BLAKE, PH.D., B.SC. **Conduction and Induction Pumps for Liquid Metals** (PAPER NO. 2111 U, JULY 1956)
	Written discussion on **The Non-Destructive Testing of Electric Strength of Liquids**
February 1957	PROFESSOR G. H. RAWCLIFFE, M.A., D.SC., AND I. R. SMITH, B.SC. **The Moving-Coil Regulator: a Treatment from First Principles** (PAPER NO. 2203 S)
	Written discussion on **A Short Modern Review of Fundamental Electromagnetic Theory**
February 1957	R. L. RUSSELL, M.SC., AND K. H. NORSWORTHY, B.SC. **A Stator-Fed Half-Speed Synchronous Motor** (PAPER NO. 2231 U)
	Discussion on **The Electrical Engineering Industry in the Post-War Economy** before the East Midland Centre and the North Midland Centre
	Discussion on **Design, Performance and Application of Miniature Circuit-Breakers** before the North Midland Utilization Group and the Mersey and North Wales Centre
	PART B. RADIO AND ELECTRONIC ENGINEERING (JANUARY 1957)
	See *Journal*, January 1957, page 51.
	PART C. MONOGRAPHS (SEPTEMBER 1956)
	See *Journal*, September 1956, page 570.

British Nuclear Energy Conference: Forthcoming Programme

FEBRUARY 21 *Thursday*

A meeting sponsored by The Institution of Chemical Engineers will be held at the Royal Institution, 21 Albemarle Street, London, W.1, at 5.30 p.m. (tea at 5 p.m.). The following paper will be presented and discussed:

CHEMICAL PROCESSING OF NUCLEAR FUELS R. Spence, C.B., PH.D., D.SC., and C. M. Nicholls, B.SC.(ENG.).

For synopsis see the January issue, p. 39.

MARCH 5 *Tuesday*

A meeting sponsored by The Institution of Civil Engineers will be held in the building of that Institution, Great George Street, London, S.W.1, at 5.30 p.m. (tea at 5 p.m.). The following paper will be presented and discussed:

BEHAVIOUR OF RADIOISOTOPES IN SEWAGE TREATMENT AND THE DISPOSAL OF RADIOACTIVE WASTES TO SEWERS A. W. Kenny, M.A., B.SC.

For synopsis see the January issue, p. 39.

MARCH 12 *Tuesday*

A meeting sponsored by The Institution. See 'Forthcoming Events at Savoy Place', p. 120. Synopses of the two papers appear on p. 116.

APRIL 2 *Tuesday*

A meeting sponsored by The Institution of Chemical Engineers will be held at the Royal Institution, 21 Albemarle Street, London, W.1, at 5.30 p.m. (tea at 5 p.m.). The following paper will be presented and discussed:

THE AQUEOUS HOMOGENEOUS REACTOR R. Hurst

We expect to publish a synopsis next month.

Unless otherwise stated, tickets of admission are not required by members of The Institution and the other constituent societies for meetings of the British Nuclear Energy Conference. An announcement about new constituent societies of the Conference appears on page 126.

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 6th December 1956.

ELECTIONS

Graduates

ALLISON, Jack Douglas.
ARTHUR, Robert Magnus.
ATTWOOD, Raymond William Harold, B.SC.
BAINES, David Thomas.
BAMFORTH, Peter Malcolm.
BAMSEY, Joseph Brice Kitchener.
BARNES, Derek Albert.
BARNEY, George Charles.
BARTON, Harold Giles.
BASTABLE, Neville Edward.
BEERLING, David Mark.
BEWLEY, William.
BIL, Aleksander.
BLACKIE, John Charles.
BLEACH, William Charles.
BOLTON, Peter.
BOND, George Frederick.
BONIKOWSKI, Zbigniew, B.SC.(ENG.).
BOULD, Fred, B.SC.(ENG.).
BOX, Roy William George.
BREWER, Thomas Howard.
BRIARS, Robert David.
BROOKS, Kenneth Thomas.
BROWN, Thomas Wilson.
BRYANT, Neville John, B.SC.
BULL, William James.
BULLOUGH, John Richard.
CAVE, Alan Bidwell.
CERESA, Anthony.
CHAPMAN, Edwin Albert.
CLEGG, Michael Ernest, B.SC.(ENG.).
COOKE, Philip, B.SC.
COPEMAN, Robert Charles, B.SC.(ENG.).
CRAIG, William Reid Mure.
DA CUNHA, Benjamin Ignatius Louis.
DAWSON, George.
DEUCHARS, David Ramsay.
DIMOND, Reginald Claude.
DOBSON, Stanley.
DUNNE, Edward Patrick, B.E.
EATON, Richard.
EVANS, Leonard Duncan.
FARRELL, Roy Colin.
FARROW, Leonard Raymond.
FLYNN, Ronald John.
FORDHAM, Arthur John.
FRITH, Peter.
FROGGATT, John.
FULLER, Edward Louis.
GARDNER, William Terah.
GELL, Peter William.
GIBBONS, Brian Joseph.
GLOVER, Kenneth John.
GOLDING, Alan William.
GORSE, Allan.
GREENWOOD, John.
GROGAN, Robert.
HATCH, Ralph George.
HAYMAN, Eric Edward.
HAYWARD, Arthur Lavender.
HEALY, Peter Cave Fletcher.
HEDLEY, Alister Talbot.
HENDERSON, Derek Carstairs.
HENRY, Alan George.
HILL, Alan William.
HORN, Peter John.
HOYLAND, Geoffrey, B.SC.(ENG.).
HUGHES, Fred.
HUGHES, Geoffrey.
HUGHES, Robert.
HUNT, Gerald Leslie.
JACKSON, Ronald Albert.
JARMAN, John Derek.
JONES, Evan Oglith.
KACMARCZYK, Frank Peter.
KLEINER, Victor.
LEE, John James.
LEVERS, Carl Cyril.
LINGER, Frederick James, B.SC.(ENG.).
LONGTHORN, John Thomas.
LORIMER, Dennis William.
MCCREDIE, William Cedric, B.SC., B.E.
MCCULLOCH, James Harold.
MCGUIRE, Kenneth William.
MCMILLAN, Philip Ernest.
MARSH, Allan James.
MARSH, John Richard.
MASLEN, John Wesley.
MORRIS, Derek Paul.
NOLAN, Joseph Brian Augustine, B.SC.
NOTTINGHAM, Ivor.
O'BRIAIN, Niall Padraig.
OSBORN, Stanley Robert.
OWEN, Hugh James.
OWENS, William Maurice.
PEARSON, James.
PENNACK, Christopher.
PENNEY, Brian Henry.
PICKBOURN, James Henry.
POINTON, Maurice.
RICHARDSON, Peter Kendall, B.SC.(ENG.).
RIDLEY, Albert Allan.
ROBB, Sidney Winning.
ROBINSON, Stephen Joseph, B.A.
ROFFEY, George Frederick.
RUSSELL, Stanley.
SAMPEYS, Alfred Marcos, B.SC.(ENG.).
SHEARDOWN, George Alan.
SIBLEY, Kenneth John.
SIMPSON, Keppel Moore, B.ENG.
SIVYER, Raymond Frank.
SMITH, Roderick MacLean.
STOCKS, Thomas.
SUNDERLAND, Flt.-Lt.*Kenneth, B.SC.
SWEET, Bryan James, B.ENG.
TAYLOR, Vivian Charles.
TOMLINSON, Leonard Victor.
VALE, Gordon Thomas.
VANES, George Edward.
WAGGOTT, John Edward.
WALKER, Herbert.
WARE, James Anthony, B.E.
WARREN, Herbert.
WATT, Sylvester Geddes Johnston.
WHEELER, Peter Frederick Charles.
WIFFEN, Norman.
WILLIAMS, Dennis Frederick.
WOOD, Dennis Jeffrey.
WOOD, Frederick Olton.
WOOLLAND, John Samuel.
WRIGHT, Hubert, B.SC.(ENG.).
WRIGHT, Percy.
YOUNG, Gavin.

Students

ALI, Sec.-Lt. Sadaqat, B.SC.(ENG.).
ANDREWS, Stanley Henry.
AYIKU, Moses Nee Buernor.
BARCLAY, David.
BENNETT, James Robert.
BINNING, George.
BISWAS, Amiya Kumar.
BOLEY, Terence Alan.
BOOTH, Robert.
BOSE, Ajit Kumar, B.SC.
BRACHER, Peter Charles.
BRADLEY, David.
BROWN, Michael Edwin.
BURFOOT, George.
BURRELL, Laurence, B.SC.
BUTLER, David John
CHOW, Daniel Jonathan Ewing.
CLEMO, Richard Philip David.
COCK, Brian Harris.
COLES, David George.
COLLIN, David John.
COMBRIDGE, Michael Lewis.

Students (contd.)

COX, Graham Goodridge.
CUTHBERTSON, Norman Edward McOuat.
D'ANDRADE, Jayme Henry.
DEMPSEY, Hartpole Baxter.
DIXON, Cecil Jack.
DOWNES, William.
ELLIS, Hugh William.
FITZPATRICK, Hugh Ivor Brunton.
FROUD, Royston John.
GARRATT, Derek Herbert.
GENT, Colin Michael.
GHEE, John Colin.
GHOSH, Biman Behari.
GIBSON, Hugh.
GILL, Harbhajan Singh, B.SC.
GILLING, Geoffrey.
GIRDLER, John.
GLEN, Alistair William Martin.
GOODING, Richard Keith.
GOOSEY, Norman Frederick.
GOYAL, Jagdish Prasad, B.E.
GUPPY, John Reginald.
GUPTA, Someshwar Chandor, M.A.
HADFIELD, Frederick William.
HARDING, John Keith.
HARDMAN, Edmund Peter.
HEYS, Frederick Arthur.
HILL, Michael Roland.
HO, Hin-Hung.
HORSPOOL, Peter Robert.
HOYLE, Keith Bayley.
JACKSON, Raymond Leslie.
JOHNSON, Philip Ian, B.SC.
KANTARIZIS, Emmanuel.
KAPOOR, Madan Mohan, B.SC.
KELSEY, Michael Edward.
KNOX, Barry Sydney David.
LARSSEN, Björn.
LAWTON, Philip John.
LORD, Geoffrey Harold.
LUND-MATHIESEN, Per.
MACMILLAN, Wilson Orr.
MALLARD, Terrance John.
MILLWARD, John David, B.SC.
MOSBY, John Denis.
MUIR, Richard Angus.
NRI, Cyril Onuora.
NUTTALL, David Arthur, B.SC.TECH.
PALMER, John.
PAUL, David Samuel.
PEARS, George Arthur.
PEARSON, Robert Keith.
PETTIE, Donald Gordon.
PROCTOR, John Howard, B.SC.
RASTOGI, Surendra Nath, B.SC., B.SC.(ENG.).
REAVILL, Barry.
REES, Raymond.
REX, Michael Graham.
ROBERTS, Allan David.
ROY, Ashis Kumar Dutta, B.SC.
SCORER, James William.
SLOANE, Idris Alun.
SMITH, Roger.
STOCKLEY, Robert Ezra James.
SULLY, David Alan.
TEMPLE, Robert.
TENNANT, David.
THOMPSON, Iain Stead.
VAUGHAN, Peter.
WIDNALL, Michael Kevin.
WIJEYEKOON, Albert Lalith Gerard.
WILSON, Peter Michael.
WIN, Maung.

TRANSFERS

Student to Graduate

ANDERSON, George Daniel.
BAKER, Ernest Norman, B.SC.
BEALE, Peter Henry.
BELL, John Stanley.
BERRINGTON, Peter William.
BLACKMORE, James John.
BOCARRO, Leonard James, B.SC.
BONNER, Clive Edwin.
BRADBURY, Ian John.
BRADNAM, Ronald Hastings.
BROOK, Donald, B.SC.(ENG.).
BROUNCKER, Anthony Charles John.
BROWN, Derek Standring, B.SC.
BROWN, Michael, B.SC.TECH.
BULL, Norman Alan.
BUNYAN, Michael John.
BURNS, Donald.
BUSH, Cyril Roy.
BUTLER, John Sydney, B.SC.(ENG.).
CHARLESON, William Andrew.
CHESMOND, Colin John, B.SC.(ENG.).
CLIFFORD, James Stewart.
COLE, George.
CONNELL, Keith Miller.
CORIN, Richard Arthur, B.E.
CORNER, Charles Bartlett.
CUPIT, Robert William.
DE SILVA, Hirimutugodage Eardley Gilbert Fredrick, B.SC.(ENG.).
DILNOT, Brian Sydney.
DIX, Dennis Lee.
DODD, Philip John.
DOSHI, Vijaykant Chunilal, B.SC.
ELLIOTT, Ronald.
ELLIS, Robert Thomas.
FISHER, Alan Oliver.
FITZROY, David, B.SC.(ENG.).
FLETCHER, Michael Brian.
FLINT, Leslie Thomas.
GEARING, Gerald Richard.
GENTY, Ronald.
GEORGE, Gerald Arthur.
GERMAN, James Colin, B.SC.(ENG.).
GIBBS, Clive.
GODDARD, Denis Brian Bridge.
GOGERLY, Peter Robin.
GREEN, Peter Alec.
HANCOCK, Bernard Wilson.
HARKNETT, Maurice Richard.
HARMAN, Ronald James.
HEALD, Leslie, B.A.
HODGSON, William Douglas, B.A.
HOLDER, John Eric.
HOLGATE, Joseph, B.SC.(ENG.).
HOLL, Raymond George.
HOLMES, Ronald Frederick.
HOWARD, Peter John.
HUGHES, James, B.SC.
HUMPHREYS, Brian Clifford.
IVESON, William Leonard.
JACKSON, George Eric.
JACQUES, John Stuart.
JONES, Frederick Peter, B.SC.
KASLER, Raymond.
KING, Arnold Raymond.
LAMB, Peter Gerald.
LAMBERT, Douglas John Sidney.
LAWRENCE, Dennis Ivan.
LEACH, William Ian, M.SC.
LINDSAY, Peter James.
LORD, Alan Ewart, B.SC.TECH.
LOWNDS, Roylance, B.SC.(ENG.).
LUFFMAN, Anthony.
MCCONNELL, Robert.
MARKS, Michael Frederick, B.SC. (ENG.).
MOORE, Francis John.
NASH, William.
NICOL, William MacCalman, B.SC.TECH.
NORCLIFFE, Joseph.
NORTHCOTT, Roland Anthony.
OUTRAM, John Frederick.
OWEN, David Guy.
PAINTER, Michael John.
PAINTON, Ronald Edwin.
PARKS, John Ronald.
PARKS, Raymond, B.SC.
PEARCE, Donald Thomas.
PENNINGTON, Christopher John, B.SC.(ENG.).
POPE, Gerald.
PRIME, Alec James.
RAY, John William, B.E.

Student to Graduate (contd.)

RHEINBERGER, Brian Philip, B.E.
ROBINSON, David, B.SC.
RODWELL, Edgar, M.SC.
ROSE, John.
SAMARANAYAKA, Dickson Perera.
SANDERS, Kenneth James.
SAVAGE, Leslie Arthur William.
SCOTT, Brian George.
SCOTT, John Cessford.
SEALEY, John Aigham.
SHARPE, Gordon Brian, B.E.
SIMMONDS, Peter Charles.
SINGH, Raminder, B.SC.
SMITH, Geoffrey Arthur, B.SC.(ENG.).
SMITH, Roy Barrington.
STEWART, Robert Michael, B.SC.(ENG.).

Student to Graduate (contd.)

STRACHAN, Kenneth Robert.
SYMES, John Henry.
TREADGOLD, Jack Richard.
VAUGHAN, Robert David.
VEEVERS, Michael Foster.
VENEIK, Amar Nath, B.SC., B.SC.(ENG.).
WADHWA, Joginder Pal, B.SC.(ENG.).
WALKER, Peter Jeremy.
WARDMAN, Donald Briscoe.
WATSON, Rex.
WEST, Charles Frederick.
WHITELEY, Stephen Ben.
WHITTAM, Peter, B.SC.
WILSON, Arthur Ronald.
WRIGHT, Richard William, B.SC.(ENG.).

**Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members.*

LIBRARY ACCESSIONS

BOOKS

ASTBURY, N. F. 537

Introduction to Electrical Applied Physics*

London, Chapman and Hall, 1956. pp. xi, 241. 22 × 14 cm. 36s.

An introduction, for advanced students, to those subjects which are not properly physics or engineering. The treatment is mathematical and the rationalized M.K.S. system is used throughout. The subjects discussed include magnetic fields, transducers, the transistor and other electronic devices, and electromagnetic-wave propagation.

BELL, D. A. 621.392

Information Theory and its Engineering Applications*

2nd edition, London, Pitman, 1956. pp. viii, 174. 22 × 14 cm. 25s.

The results of recent developments in the subject are presented in a way which a professional engineer should be able to follow. In this new edition the chapter on coding has been expanded and there is a new chapter on decoding.

BEVITT, W. D. 621.314.7

Transistors Handbook*

Englewood Cliffs, Prentice-Hall, 1956. pp. xiv, 410. 22 × 14 cm. £3 3s.

A practical work containing much useful information. It describes the properties of point-contact and junction types, power transistors, tetrode and pentode types, photo-diodes and photo-transistors. The measurement of characteristics is described and details given of particular types. Practical circuits are then reviewed and typical values of components indicated. The book was reviewed in the December issue.

BUCKINGHAM, H., and PRICE, E. M. 621.31

Electro-Technology for National Certificate Courses. Vol. II

London, English Universities Press, 1956. pp. xiii, 298. 22 × 14 cm. 12s. 6d.

The book more than covers the syllabuses of the second year of a National Certificate Course. The M.K.S. system, which is explained in the first chapter, is used throughout and there are worked examples and problems for the student to work. Volume 1 of the series was by Teasdale and Walton.

CHERRY, C. (Editor)

Information Theory* Papers read at a symposium on 'Information Theory' held at the Royal Institution, London, September 12th to 16th 1955

London, Butterworths, 1956. pp. x, 401. 25 × 15 cm. £3 10s.

The first symposium dealt with the mathematical and philosophical basis of the subject and the second with applications to telecommunication. The present series of papers illustrates the manner of interpretation and the value of information theory to a variety of disciplines. They are arranged in five groups—fundamentals, coding and taxonomy, language analysis and mechanical translation, meaning, and behaviour and its mechanism.

COCKING, W. T. 621.396.62

Wireless servicing manual*

9th ed. London, Iliffe, 1956. pp. viii, 268. 22 × 15 cm. 17s. 6d.

A completely revised and reset edition of a well-known work. It deals with problems met in servicing both straight and superheterodyne receivers and gives much information useful to the home constructor. The chapter on television receivers has been replaced by one on f.m. receivers.

COTTON, H. 621.3

Electrical Principles*

London, Cleaver-Hume Press, 1956. pp. xii, 382. 19 × 13 cm. 12s. 6d.

Covers the requirements of O level General Certificate work and is appropriate for first- and second-year senior courses in technical colleges. The M.K.S. system is used throughout and the approach to the subject is through the atom and electron. It is attractively illustrated and contains worked examples and problems for the student.

CROWTHER, J. G. 621.039

Nuclear Energy in Industry*

London, Newnes, 1956. pp. vii, 168. 22 × 14 cm. 17s. 6d.

This book, written for the non-specialist, is based on the author's attendance at the International Conference on The Peaceful Uses of Atomic Energy. A survey of the world's remaining resources of consumable fuels and the rate at which they are being used is followed by an estimate of the transition to a condition in which unlimited power from nuclear energy will be available. The various types of reactor and nuclear power plant are described and the many industrial applications of isotopes discussed. Problems associated with the mining, metallurgy and handling of uranium are indicated. An interesting and lucid account, containing many data, illustrations and diagrams. This book will be reviewed in a future issue.

DAWES, C. L. 621.31

Industrial Electricity. Vol. I. Direct Currents

3rd ed. New York and London, McGraw-Hill, 1956. pp. xv, 431. 24 × 16 cm. £2 1s. 6d.

A new edition of a two-volume elementary work for electrical engineering students. It is an introduction to the subject, progressing as far as generators and motors.

DOVER, A. T., CHAPMAN, F. T., BRAILSFORD, F., and CARTER, H. 621.31

Electrical Engineering (General)*

London, Longmans, Green, 1956. pp. ix, 489. 25 × 16 cm. £2 10s.

This introductory volume in a series suitable for degree and Higher National Certificate courses in electrical engineering, gives the

necessary fundamental knowledge of circuit relations, measurement, insulation, magnetism, and materials. The subjects of waveform analysis and electronic apparatus are covered from the power engineering point of view. Examples and answers are given throughout. This book is reviewed on p. 118.

DRAPER, A. 621.313

Electrical Machines*

London, Longmans, Green, 1956. pp. xvi, 346. 25 × 16 cm. £2

This book is for use with others in a series addressed to students for degrees or Higher National Certificates: it is not primarily intended for professional designers. The common features of machines and their magnetic circuits are studied and lead to more detailed chapters on individual types including commutator machines, rotating amplifiers and inductor alternators. The scope of the book includes transformers and rectifiers and there are numerous questions, with solutions. This book is reviewed on p. 118.

E.L.M.A. LIGHTING SERVICE BUREAU 621.32

Electric Lamps*

London, E.L.M.A., 1955. pp. viii, 149. 22 × 14 cm. 10s.

Describes briefly the history of the subject, the nature and production of light, and lamp manufacture. Details of modern filament, discharge and special-purpose lamps are concisely presented, largely by diagrams, tables and illustrations.

FISHER, D. H. 621.397.62

V.H.F. Television Tuners*

London, Heywood, 1956. pp. vii, 136. 22 × 14 cm. 21s.

Discusses the theory and fundamental problems of tuner design, then deals in a practical way with considerations involved in constructing, testing and servicing tuners. It is a comprehensive treatment and contains a great deal of practical information including actual values of components. This book is reviewed on p. 119.

FLÜGGE, S. (Editor) 53

Handbuch der Physik. Band XVII. Dielektrika (Encyclopedia of Physics. Vol. XVII, Dielectrics)

Berlin, Springer-Verlag, 1956. pp. vi, 406. 25 × 16 cm. £6 11s. 7d.

This volume comprises three very long chapters. The first deals generally with dielectrics in their varying forms, the second, which is in German, is concerned with dielectric breakdown, and the third with piezo-electricity, electrostriction and ferroelectricity. Each chapter is followed by an extensive bibliography.

FLÜGGE, S. (Editor) 53

Handbuch der Physik. Band XXI. Elektronen-Emission Gasentladungen I (Encyclopedia of Physics, Vol. XXI. Electron-Emission Gas Discharges I)

Berlin, Springer-Verlag, 1956. pp. vii, 683. 25 × 17 cm. £9 4s. 10d.

This volume is mainly in English and includes chapters on thermionic emission, photoionization in gases, photoelectric emission from solids, ionization in gases by electrons in electric fields, the formation of negative ions and the motions of ions and electrons.

FRASER, N. (Editor) 92 (MAC)

Sir Edward MacColl: a Maker of Modern Scotland*

Edinburgh, Stanley Press, 1956. pp. 64. 22 × 14 cm. 12s. 6d.

This interesting bibliographical sketch, to which a number of authors have contributed, gives a picture of the man and his work. He will be remembered chiefly for his interest in the development of electric power for Scottish industry and in particular for his enthusiastic support for schemes for harnessing the water power of the Highlands. He directed his efforts, too, towards achieving an electricity Grid for Scotland.

GARNER, R. H. 621.39.049

Mechanical Design for Electronic Engineers*

London, Newnes, 1956. pp. vii, 223. 22 × 14 cm. 25s.

A practical work on the mechanical aspects of equipment design and construction, including rack systems, cabinets, chassis and sub-panel construction, accessibility, ventilation and vibration. Discusses printed circuits and components, soldering and labelling, and devotes a short chapter to special-quality valves.

GIET, A. 518.3

Abacs or Nomograms. An introduction to their theory and construction illustrated by examples from engineering and physics*

London, Iliffe, 1956. pp. ix, 225. 22 × 14 cm. 35s.

A practical work, translated from the French, which demonstrates the many and varied applications of Abacs and shows how they may be constructed without highly specialized knowledge. It deals with both Cartesian Abacs and alignment charts giving practical examples in physics and mechanical and electrical engineering. This book will be reviewed in a future issue.

HUGH-JONES, E. M. (Compiler) 658.2

Automation in Theory and Practice*

Oxford, Basil Blackwell, 1956. pp. ix, 140. 19 × 13 cm. 12s. 6d.

A serious treatment of automation and the problems it evokes in its varying aspects, seen in turn, through the eyes of an engineer, a trade unionist, a business consultant, a sociologist, an economist and two scientists. This interesting book is based on a group of seven lectures given at Oxford in 1955 before a predominantly undergraduate audience.

HUNTER, P. V., and HAZELL, J. TEMPLE 93 : 621.315

Development of Power Cables*

London, Newnes, 1956. pp. 150. 22 × 14 cm. 25s.

This is an objective and accurate history based on careful research over a period of years. It contains many illustrations, mainly of specimens in the Hunter–Hazell Collection of cables in the Science Museum, which is considered to be the most comprehensive in the world. This book was reviewed in the January issue.

HURST, R., and McLAIN, S. (Editors) 61.039

Technology and Engineering Reactor Coolants, Moderators, Heat Transfer, Reactor Chemistry and Corrosion of Reactor Materials. Series IV. Volume 1.*

London, Pergamon Press, 1956. pp. xiii. 420, 23 × 15 cm. £4 4s.

Many of the papers in this volume are reviews of present-day knowledge as revealed at the International Conference on The Peaceful Uses of Atomic Energy. They cover the technology of coolants and moderators, of heat transfer, and of corrosion and other chemical problems arising from intense radiation fields within the nuclear reactor.

JAY, K. 621.039

Calder Hall. The story of Britain's first atomic power station*

London, Methuen, 1956. pp. vii, 88. 19 × 12 cm. 5s.

An interesting non-technical account of the planning and construction of Calder Hall. It describes in full the first day of actual operation and the safety precautions which were taken.

JONES, J. D. 621.396.619

Frequency Modulation Receivers*

London, Heywood, 1956. pp. ix, 114. 22 × 14 cm. 17s. 6d.

A practical work which explains the reasons for using f.m. for high-quality reception and indicates the difference between a.m. and f.m. receivers; it summarizes the essential requirements for an f.m. receiver. The various stages of a receiver are discussed, and methods of obtaining the correct alignment and measuring performance are described.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH JANUARY 1957

	No. of Contributors	£	s.	d.
£1 000 and over	6	6000	0	0
£100 to < £1 000	30	6586	3	0
£5 to < £100	817	8736	8	3
£2 to < £5	1956	5340	0	2
Under £2	20781	10834	6	8
		£37496	18	1

HONOURS AND DISTINCTIONS CONFERRED ON MEMBERS

The names of the following members of The Institution were included in the list of New Year Honours and Distinctions conferred by Her Majesty:

ORDER OF MERIT

Cockcroft, Sir John D., K.C.B., C.B.E., M.A., D.SC., M.SC.TECH., PH.D., F.R.S. (*Member*).

KNIGHT BACHELOR

Dean, J. N. (*Companion*).
Eccles, J., C.B.E., D.SC. (*Member*).

KNIGHT COMMANDER OF THE ORDER OF ST. MICHAEL AND ST. GEORGE

Angwin, Col. Sir A. Stanley, K.B.E., D.S.O., M.C., T.D., D.SC.(ENG.) (*Hon. Member*).

COMPANION OF THE ORDER OF ST. MICHAEL AND ST. GEORGE

Halsey, R. J., B.SC.(ENG.) (*Member*).

COMMANDER OF THE ORDER OF THE BRITISH EMPIRE

Fulton, A. A., B.SC. (*Member*).
Humphreys, O. W., B.SC. (*Member*).

OFFICER OF THE ORDER OF THE BRITISH EMPIRE

Alder, C. D., B.SC. (*Associate Member*).
Hough, F. A., M.SC.(ENG.) (*Associate Member*).
James, E. G., B.SC., PH.D. (*Associate Member*).
McCarthy, Lt.-Col. D. W. C., M.B.E., M.A., R.E. (*Associate Member*).
McKearney, P. (*Member*).
Roche, A. H., B.SC.(ENG.) (*Associate Member*).
Roots, A. E. (*Member*).

MEMBER OF THE ORDER OF THE BRITISH EMPIRE

Collins, A., B.SC.(ENG.) (*Member*).
Warren, W. (*Member*).
Webbe, Capt. D. B., R.E. (*Associate Member*).

FARADAY MEDAL

At an Ordinary Meeting of The Institution on the 10th January 1957, the President announced that the Council had made the Thirty-Fifth Award of the Faraday Medal to **Dr. Waldemar Borgquist,** lately President of the Swedish State Power Board, for his outstanding contributions to the development of electricity supply and transmission, particularly at extra-high voltages, and for his long-standing interest in the education and training of engineers.

HONORARY MEMBERS

At an Ordinary Meeting of The Institution on the 10th January 1957, the President announced that the Council had elected two new Honorary Members:

Sir Noel Ashbridge, B.Sc.(Eng.), Past-President, in recognition of his distinguished services to The Institution and his outstanding contributions in the field of radio engineering, particularly in the development of the British sound and television broadcasting services.

Brigadier-General Sir Harold Hartley, G.C.V.O., C.B.E., M.C., M.A., F.R.S., in recognition of his life-long interest in all aspects of engineering science, and for his studies of the conservation of natural resources.

SCHOLARSHIPS

The Council invite applications for the following scholarships which are offered for award this year:

RESEARCH SCHOLARSHIPS

I.M.E.A.	Value £420 for one year; may be extended
Oliver Lodge	Value £420 for one year; may be extended
Swan Memorial	Value £120 for one year; which may be increased in exceptional circumstances
C. P. Sparks Fund	Maximum grant £100

GRADUATE SCHOLARSHIPS (*for full-time post-graduate study*)

Duddell	Value £400 for one year
Silvanus Thompson	Value £400 for one year

STUDENT SCHOLARSHIPS (*for study at undergraduate level at a university or a technical college*)

**Duddell*	Value £200 p.a. for three years
**Silvanus Thompson*	Value £200 p.a. for three years
Sir Arthur Fleming	Value £120 p.a. for four years
Paul	Value £75 p.a. for four years (This may be increased for an exceptional student)
Salomons	Value £60 for one year
David Hughes	Value £60 for one year
Sir Charles A. Parsons	Value £60 p.a. for three years
Thorrowgood	Value £25 for one year

The closing date for the receipt of application forms for the Student Scholarships is the 1st May 1957, and for Graduate and Research Scholarships the 1st June 1957.

THE ANNUAL DINNER

The number of applications from members wishing to attend the Annual Dinner has greatly exceeded the accommodation available, and there is now a waiting list for returned tickets.

Members who have already received tickets and subsequently find they are unable to attend are asked to return them without delay, so that their places can be allocated to members on the waiting list.

* The Duddell and Silvanus Thompson Scholarships will not be available as Student Scholarships if they are awarded as Graduate Scholarships.

WIRELESS TELEGRAPHY ACT 1949

APPOINTMENT OF ADVISORY COMMITTEE ON INTERFERENCE FROM INDUSTRIAL SCIENTIFIC AND MEDICAL EQUIPMENT

The Postmaster General made, on the 1st November 1956, an announcement in the following terms:

'I hereby appoint, in accordance with Section 9, subsection (2), of the Wireless Telegraphy Act, 1949,

Mr. O. W. Humphreys, B.SC., M.I.E.E. (*Chairman*)
Mr. P. Adorian, M.I.E.E.
Dr. P. Bauwens, M.R.C.S., L.R.C.P.
Mr. J. I. Bernard, B.SC.TECH., M.I.E.E.
Mr. P. A. T. Bevan, B.SC., M.I.E.E.
Sir Harold Bishop, C.B.E., B.SC.(ENG.), M.I.MECH.E., M.I.E.E.
Mr. N. R. Bligh, B.SC.(ENG.), A.M.I.E.E.
Mr. A. H. Cooper, B.SC.
Mr. H. Faulkner, C.M.G., B.SC.(ENG.), M.I.E.E.
Mr. J. S. Forrest, M.A., D.SC., M.I.E.E.
Lt.-Col. M. O'C. Horgan, O.B.E., M.SC., M.I.E.E.
Mr. B. B. Jacobsen, B.SC.(ENG.), A.M.I.E.E.
Mr. C. W. Miller, F.INST.P.
Mr. F. S. Milligan
Mr. Paget Bowyer, B.SC.(ENG.), M.I.E.E.
Mr. E. L. E. Pawley, O.B.E., M.SC.(ENG.), M.I.E.E.
Mr. C. N. Rocky
Mr. P. Styles
Mr. R. W. J. Sullivan

to be members of the committee on interference from industrial, scientific, and medical equipment that I shall require to consult, before I make regulations under section 10 of the Act, on matters concerning the requirements to be complied with for the purpose of ensuring that the use of industrial, scientific, and medical equipment does not cause undue interference with wireless telegraphy.

'The secretariat of the committee will be provided jointly by The Institution of Electrical Engineers and the Post Office, and any correspondence about the committee should be addressed to: The Secretary, Postmaster General's Advisory Committee on Wireless Interference from Industrial, Scientific, and Medical Equipment, The Institution of Electrical Engineers, Savoy Place, London, W.C.2.'

CORRESPONDENCE IN THE *JOURNAL*

The Editor welcomes short letters on aspects of electrical engineering science and technology or on current electrical engineering events; such letters will as a rule be accepted for publication in the *Journal*. In particular, an author intending to submit a paper on a rapidly developing subject for publication in the *Proceedings* is asked to consider making a brief preliminary announcement of the most important material to be contained in his paper, by means of a communication to the *Journal* before the paper is completed. Letters for publication should be less than 750 words long, together with a few illustrations if required. Two copies of each letter, in double-spaced typing, should be addressed to the Editor and marked 'For Publication'.

HOMES OF OTHER ENGINEERING SOCIETIES

A booklet is now available entitled 'Homes of Some Engineering Societies in Western Europe and the United States of America'. Its many photographs illustrate the headquarters in which our sister institutions abroad are housed, and brief details are given of the history, size and amenities of each. They vary strikingly, from the Ruritanian 'Red Castle' of the Swiss Society of Engineers and Architects to the stylish modern buildings of the Scandinavian institutions. The booklet, which also outlines the aims and activities of the Conference of Engineering Societies of Western Europe and the United States of America (EUSEC), has been published on behalf of that body by The Institution of Mechanical Engineers. Copies may be obtained from the Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2, price 7s., post free.

BRITISH NUCLEAR ENERGY CONFERENCE

INCLUSION OF THE METALLURGICAL INSTITUTES

The Board of the British Nuclear Energy Conference, at a meeting on the 9th January 1957 under the Chairmanship of Sir John Cockcroft, decided to admit the Iron and Steel Institute and the Institute of Metals as members of the Conference.

The purpose of the B.N.E.C. is to co-ordinate the nuclear-energy activities of its constituent members by holding meetings and publishing a journal. Its recent Symposium on Calder Hall was attended by 1 800 delegates from all over the world.

The original members of the B.N.E.C. were The Institutions of Civil, of Mechanical, of Electrical and of Chemical Engineers, and The Institute of Physics. The Board have for some time felt that the Conference would be strengthened by including representatives from the field of metallurgy.

1946 RADIOLOCATION CONVENTION

The large number of papers read at the above Convention were subsequently published, together with their discussions, in a series of special issues of the *Journal*. The first was a Special Number, identified as Part IIIA, No. 1, containing all the survey papers and lectures delivered at the Convention and also informative abstracts of the supporting papers. This was followed by nine Supplements (Part IIIA, Nos. 2–10) containing the full text of the supporting papers and any discussions on the survey papers.

Of the above ten issues, copies are still available of Nos. 1, 9 and 10, but Nos. 2–8 have for some time been out of print. Requests are still received from time to time for certain of these issues, and in particular for No. 7 'Circuit Techniques for Radiolocation', and the question of reprinting has arisen. Accordingly anyone who would be interested in obtaining one or more of these special issues, the average price of which would probably be about 15s. each to members, and 22s. 6d. to non-members, is requested to communicate with the Secretary, stating the particular number or numbers he wishes to have. In the light of the replies received it will be decided whether the high cost of reprinting any of the numbers would be justified. **No remittances should be sent at this stage.**

A detailed list of the issues, indicating the subjects with which they deal, is given below:

Out-of-print issues

No. 2 Naval Gunnery Radar. Radar Navigation. Precision Radar.
No. 3 Propagation. Aerials—I: Metre-Wave.
No. 4 Aerials—II: Centimetre-Wave.
No. 5 Cathode-Ray Tubes. Valves.

No. 6 Transmitters and Receivers.
No. 7 Circuit Techniques for Radiolocation.
No. 8 Radio Measurements and Test Gear (General).

Issues still available	*Price to Members*	*Non-Members*
No. 1 Survey Papers and Lectures, and Abstracts of Supporting Papers	6s.	£1
No. 9 Radio Measurements and Test Gear (Centimetre-Wave)	3s.	6s.
No. 10 Miscellaneous Papers not included in Nos. 1–9	3s.	6s.

WORLD POWER CONFERENCE

SECTIONAL MEETING IN YUGOSLAVIA

A sectional meeting of the World Power Conference will be held in Belgrade, Yugoslavia, in June 1957. Seventéen of the papers to be presented will originate from Britain. The meeting will last seven days, probably from the 5th to 11th June, and will be followed by a series of study tours. The programme and membership application forms are now ready and may be obtained from the British National Committee, World Power Conference, 201–2 Grand Buildings, Trafalgar Square, London, W.C.2.

HARWELL REACTOR SCHOOL

BASIC COURSE IN NUCLEAR ENERGY

The present standard course at the Harwell Reactor school of the United Kingdom Atomic Energy Authority lasts fourteen weeks and covers primarily reactor physics and engineering. Although the existing arrangements allow some students to attend only the first six weeks of the course, to acquire a grasp of the basic principles of the subjects taught, the numbers of places available for such students have been rather limited. However, a special basic course for sixty students will take place from the 3rd June to 12th July 1957. The course will include lectures on reactor metallurgy, shielding and health physics. It will also emphasize special topics such as reactor instrumentation and the use of radio-isotopes in industry, a subject not included in the standard course.

The special six-week course is designed mainly for men and women of degree standard, who are concerned with ancillary reactor equipment rather than the design of whole reactors. Application forms and further information may be obtained from the Reactor School, A.E.R.E., Harwell, Berkshire.

THE PHYSICS OF COLOUR TELEVISION

INTERNATIONAL SYMPOSIUM IN PARIS

An International Symposium on Physical Problems of Colour Television will be held in Paris from the 2nd to 6th July 1957. This is being sponsored by the International Union of Pure and Applied Physics, the Société Française des Radioélectriciens and the Société Française des Ingénieurs et Techniciens du Vide. The symposium will furnish an opportunity of gathering and discussing data relating to many physical problems which may be summarized under the following four headings:

1. Properties and Behaviour of the Human Eye in Colour Television
2. Image Analysis and Restitution
3. Assessment and Measurement of Picture Quality
4. Coding procedures for Transmission of Colour Signals

The above four groups are not exhaustive, and papers on all relevant subjects will be considered for inclusion. Anyone intending to submit a paper for reading at the symposium should forward it in abstract before the 1st May 1957.

The organizers hope that an experimental transmitter will, during the meeting, broadcast colour-television programmes on various existing systems. There will be facilities for authors who wish to demonstrate apparatus. Technical visits and discussions will be arranged during the meeting. Further information about the symposium may be obtained from the Secretary, Colloque International sur les Problèmes de la Télévision en Couleurs, Conservatoire National des Arts et Métiers, 292 rue Saint-Martin, Paris 3e.

CONFERENCE ON NUCLEAR ENERGY

A Conference, for managers, on the subject of nuclear energy is being organized by the O.E.E.C. European Productivity Agency and will be held in Paris from the 1st to 6th April 1957.

The Conference is addressed to industrialists and is intended to provide information on the present stage of nuclear technical development, the economic prospects offered by such development, the problems of the construction and operation of nuclear plant, and the industrial use of radio isotopes.

Papers will be read by members of the nuclear energy organizations of O.E.E.C. countries and by industrialists directly concerned with work on nuclear energy. Further information may be had from the O.E.E.C. Information Division, Château de la Muette, 2, rue André-Pascal, Paris, XVIe.

STUDENT REFUGEES FROM HUNGARY

Members who have already responded to the President's appeal circulated last month are warmly thanked for their support of the Scholarship Fund for Hungarian Electrical Engineering Students; separate acknowledgements are being sent. The subscription list is still open, and cheques should be made payable to 'The Honorary Secretary, The Scholarship Fund for Hungarian Electrical Engineering Students' and sent c/o The Institution. The Fund will be administered by a Committee of Council who will co-operate with other similar funds.

SUMMER MEETING 1957

Applications to take part in the Summer Meeting of The Institution, to be held in the area of the North-Western Centre from the 1st to 5th July 1957, are now being received in response to the circular and reply form about the Meeting which was sent to all members with the January *Journal*. Members wishing to take part in the Meeting are advised to send their applications as soon as possible.

The Buffet Dance on Friday 5th July, for which the hosts are the Metropolitan-Vickers Electrical Co., will take place at the Manchester Free Trade Hall, and not at the Midland Hotel as stated in the circular.

ASSOCIATION OF FINNISH ENGINEERS

On the 1st January 1957 the Suomalaisten Teknikkojen Seura changed its name to 'Suomen Teknillinen Seura'. The approved English translation of the Society's name will continue to be 'The Association of Finnish Engineers'.

RAILWAY PANEL OF CONSULTANTS

The British Transport Commission have appointed a panel of consulting engineers to advise their chief engineers on technical problems associated with a.c. railway electrification.

Members of the panel are Mr. G. F. Kennedy, M.A., M.I.MECH.E., MEMBER, Mr. J. S. Tritton, M.I.C.E., M.I.MECH.E., and Mr. E. L. E. Wheatcroft, M.A., M.I.MECH.E., MEMBER.

NUCLEAR CONGRESS IN PHILADELPHIA

With reference to the announcement on p. 776 of the December 1956 *Journal*, full information about the Second Annual Nuclear Congress is now available from the Secretary, Engineers Joint Council, 29 West 39th Street, New York 18, New York. In addition to the Atomic Exposition this 1957 Nuclear Congress (from the 11th to 15th March) will include conferences on Atomic Energy in Industry and on Hot Laboratories and Equipment.

ELECTRICAL RESEARCH ASSOCIATION

The Council of The British Electrical and Allied Industries Research Association have appointed H. G. Taylor, D.SC. (ENG.), F.INST.P., MEMBER, to be Director of the Association from the 1st April 1957, in succession to the late Dr. S. Whitehead. For the past nine years Dr. Taylor has been Director of Research of the British Welding Research Association.

FIFTY YEARS OF MEMBERSHIP

The Council take much pleasure in placing on record the completion of fifty years of membership of The Institution by the members whose names appear below; they first became associated with The Institution in the year 1907.

Adamson, E.
Aldridge, A. J.
Allan, C. T. T.
Aylmer, J., M.C.
Beard, J. R., C.B.E., M.SC.
Bissett, F. W.
Blackhall, W. J.
Blankley, G. W.
Bowers, E. G., Lt.-Col., M.C.
Bramwell, H. P.
Brecknell, F. W.
Burgess, A. B.
Cooper, H.
Crockatt, W. C., B.SC.
Davies, B.
Davis, A. A.
Dumjohn, F. P.
Eaton, G. H.
Ellis, A. H.
Elvy, J. C.
Faine, C. G. G., D.S.O.
Fairfield, G.
Francies, R., T.D.
Gaskins, F. W.
Golding, T., O.B.E.
Gould, C.
Hargrove, J.
Havelock, J. H.
Hayman, R. W.
Heath, J. S.
Henderson, M. C.
Hunt, W. S.
Kingsbury, H.
Lunn, W.
McGowan, F. A.
Maclachlan, D. S.
Manners-Smith, J. A.
Marshall, C. R.
Meredith, J.
Monkhouse, A.
Morgan, E., M.ENG.
Page, G. W. P.
Parkes, F. W.
Petithory, E. A.
Rayment, A. C.
Richards, H. W. H.
Richardson, A.
Richardson, H. W., B.SC.(ENG.).
Robertson, G. M.
Robinson, R.
Shaw, W. B.
Smith, A.
Stoneham, C. D.
Topham, F. C.
Villares, G. D.
Watkins, S. S. A., B.SC.(ENG.).
Watson, P.
Wellden, H. C.
Williams, F. H., B.SC.TECH.
Young, J. H. M.

THE BRUSSELS EXHIBITION 1958

At the Brussels Universal and International Exhibition, to be held from the 17th April to 19th October 1958, the B.E.A.M.A., in conjunction with and on behalf of several manufacturers' associations, are organizing a collective exhibit to represent British electrical engineering. This will be situated in the large British industrial pavilion, which is being organized by the F.B.I., and on which work officially began in November of last year. The Belgian authorities are planning the exhibition itself on a very large scale: 53 countries and various international organizations will be providing national pavilions and special exhibits, and the emphasis will be on scientific, industrial and cultural achievement rather than on individual products. The central physical feature of the Brussels Exhibition will be the Atomium, a 330 ft-high structure representing an iron crystal, enlarged about 2×10^{11} times, as a symbol of the coming of the atomic age. Members who are interested in the Exhibition can obtain further information about it from the Central Office of Information, London, or from the Société de l'Exposition Universelle et Internationale de Bruxelles en 1958, 10 rue de Chene, Brussels.

REPORT ON GRADUATE TRAINING

A new report on the professional electrical engineer dealing with the training of graduates was published by The Institution on the 25th January 1957. The report is the work of a Joint Committee representative of all branches of the electrical engineering industry. The members are appointed by the Council in consultation with the B.E.A.M.A., the R.I.C. and other interested bodies.

The report, which is entitled 'The Training of Graduates', brings up to date the recommendations made in an earlier report on 'The Practical Training of Professional Electrical Engineers', published by The Institution in 1947. It will be followed by a second report on the training of professional electrical engineers through student apprenticeship. The report recommends that all students who have followed a full-time course of education in engineering or science and who wish to qualify as Chartered Electrical Engineers should complete a two-year programme of training comprising: (i) basic workshop training; (ii) general mechanical and electrical training; and (iii) directed objective training.

The objects of each of these phases of training are fully discussed in the report and supplemented by representative schemes for different branches of the industry, including heavy and light electrical engineering firms, operating concerns and research establishment. For the training of graduates in small firms, group schemes covering several firms are encouraged.

Copies of the report, price 2s. post free, may be obtained from the Secretary of The Institution.

THE BENJAMIN FRANKLIN MEDAL

The Council of the Royal Society of Arts have founded a new award, to be known as the Benjamin Franklin Medal, which is to be made annually 'to individuals who have attained early distinction, with promise of future achievement, in the promotion of arts, manufactures and commerce'.

The Society has recently announced that the first recipient of the Medal will be Professor F. C. Williams, O.B.E., D.SC., F.R.S., MEMBER, who has been awarded it for his achievements in electrical engineering. Professor Williams's contributions to electronic circuit technique during the Second World War and his subsequent pioneering development of automatic digital computers are particularly mentioned in the citation.

The Medal is named after Benjamin Franklin because it was instituted in 1956, the year of both the 250th anniversary of Franklin's birth and the 200th anniversary of his election to the Royal Society of Arts.

THE RADIO SHOW 1957

The Radio Industry Council have announced that the Twenty-Fourth National Radio Show will be held at Earls Court, London, from Wednesday, the 28th August, to Saturday, the 7th September 1957.

LONDON REPORT

ORDINARY MEETING

A Classic Evening

The Ordinary Meeting held on the 6th December 1956 was dubbed 'classic' by one member, and his seems to have been a true comment. Here was an 'integrating' paper—*The Measurement of Earth Loop Resistance*—by G. F. Tagg—based upon Regulation 507 of The Institution's own *Regulations for the Electrical Equipment of Buildings*, a classic of the electrical world. Then, too, the instrument to which Dr. Tagg referred during his paper is one of the latest members of a family of such instruments, which have well earned the title 'classic'. A short review of the paper is published on p. 94.

From the time the President took the chair until he closed the meeting, there were keen interest, vigorous discussion and revelations of differing opinions and of practice. All these demonstrated the importance of the Ordinary Meetings of The Institution as a vital means of communication between engineers.

It was noticeable that not all of those who spoke were engaged in work necessarily connected directly with the Wiring Regulations or their applications. Indeed, one of the main attractions of the discussion was the widely different approaches to the problem, from the points of view of designer, teacher, user and researcher.

To summarize the discussion: it was down to earth—with some excursions into higher theory and with one unique revelation of domestic earthing procedure involving a treacle tin that was filled with soil, provided with a central electrode and placed under the kitchen sink.

Mr. Swann opened the discussion and emphasized the importance of a practical basis for the test on earth-loop characteristics, so as to ensure that protective devices operated with certainty under fault conditions. Mr. Swann echoed the sentiments of members present when he referred to the late Mr. P. V. Hunter, whose interest in the Wiring Regulations and the new National Inspection Council had been so energetic for so long a time.

The measurement of resistance or impedance gave rise to some discussion and there seemed to be a conclusion that for general practical purposes resistance measurements could suffice. Nevertheless, more than one contributor argued that modern measurement could determine impedance with accuracy, although sometimes the method might involve a calculation which a semi-skilled observer would find troublesome.

A practical approach was exemplified by Mr. Roscoe, who described an instrument in which the actual fusing current for each circuit complete with earth loop is estimated by a simple injection method. Its practical advantage—the adjustment dial is marked in fuse sizes—was emphasized, and Mr. Knight went further in suggesting that artificial faults could be just as suitable as a means of making a measurement, for the real problem is to provide a fuse which will blow when trouble arises.

Mr. J. Hall affirmed the interest of the new National Inspection Council in the problem. Earth-loop resistance involves not only the actual work done by the contractor but also the complex of neutral cables, earth plate and earth return as well. Responsibility for correct installation must, therefore, be shared.

At the end of the brisk and illuminating discussion it was quite evident that the last word has not been said on this subject, and it was equally evident that the engineers concerned are fully aware of the problems remaining to be solved.

Dr. Denis Taylor, the Chairman of the Measurement and Control Section, in proposing a vote of thanks to the author, remarked on the success of the meeting despite the petrol shortage and the number of competing engagements. He suggested that the paper, concerning itself with volts, amperes and ohms and involving no electronics, was firm ground for most members, though they must have been surprised to find that one of the instruments described during the discussion included a cold-cathode valve.

W. B.

MEASUREMENT AND CONTROL SECTION

At the meeting on the 4th December 1956 a paper on *The Absolute Calibration of Voltage Transformers* by W. K. Clothier and L. Medina was presented on their behalf by Mr. G. W. Bowdler, since the authors are living in Australia. A short review appears on p. 94. For such a specialized subject the attendance was no less than one could reasonably expect. The discussion was necessarily rather eclectic, since the paper was concerned with equipment for use essentially in standardizing laboratories, of which there are relatively few.

Mr. Bowdler prefaced a reading of the authors' own abstract of the paper by comments on the high quality of their previous work and their wide experience in the design of high-stability capacitors. Both he and they acknowledge the previous work of others, especially B. G. Churcher (thirty years ago), upon whose circuit the authors had built, to provide themselves with phenomenally high sensitivity and accuracy. This, he said, had been closely approached by equipment described within the past two years in German publications; but an accuracy of 1 part in 10000 was not yet possible at the N.P.L.

The abstract, for want of sufficient time, dealt with only the first and (in the authors' view) more important method of the two described in the paper.

Five speakers took part in the discussion, which was opened by Mr. D. Edmundson. He included in his remarks the views of Mr. J. G. Wellings, who was not able to be present. For similar reasons Mr. L. W. Pettitt read a contribution by Mr. H. D. Hawkes. Other speakers were Mr. A. Felton, Mr. S. W. Redfern, and Mr. J. K. Webb.

It was clear from the abstract and discussion that the high accuracy of ratio measurement (1 part in 10^5 at the worst) and of phase-angle-error measurement (0·05′ maximum error) had been made possible by the use of capacitor dividers employing only air-dielectric capacitors and the avoidance of mutual inductors. Thus both the effects of stray magnetic fields and the need to correct for a varying dielectric loss as capacitors are switched are eliminated. The high sensitivity derives from the use of a tuned electronic detector and from

the fact that the full secondary voltage is applied across the lower arm of the capacitor divider.

There was some criticism of both these features, namely that the first was exposed to interference from the 'buzz and fizz' (to quote one speaker) that inevitably attend high-voltage testing, especially of capacitor voltage transformers, and that the second requires the series-aiding connection of the primary and secondary windings of the transformer under test, which is the opposite of that adopted in service. These criticisms are not in fact well founded since, in both the paper and the abstract, emphasis is laid on the precautions taken to shield the capacitors and the connections between them and the sensitive electronic detector. Moreover the paper gives the results of tests taken with both the series-aiding and the series-opposing connections.

The shield or guard circuit itself came in for some criticism because (although a subsidiary balance was unnecessary since the guard circuit and detector were at earth potential) it rendered the method unsuitable for testing transformers intended for connection between lines, as opposed to line and earth.

Another criticism raised, that may well have been forestalled by the authors, was that the equipment was both frequency and waveform conscious. The small errors mentioned had been maintained over a frequency range of 20–60 c/s. On the question of waveform effect, however, there was more reticence.

More than one speaker emphasized the great practical value of the instrument as a tool which could be safely placed in the hands of any testing staff, without the risk of the errors attending instruments in which the readings are less direct and which do not possess the self-checking features that characterize the authors' equipment.

Mr. Felton was proud that both authors had spent some time at the N.P.L. and thought that that organization could modestly claim some credit for having had a small part in teaching them their trade. His tribute to the paper is worthy of note: 'The impressions I get from this paper are of elegance and ingenuity combined with that conscientious attention to detail that we have grown to expect from these authors.'

Mr. Bowdler replied to that part of the discussion which did not concern the detailed performance of the method; this he left to the authors to deal with. In the course of his reply he added his own contribution, in which he described comparable equipment at the N.P.L., and explained the general method adopted there for testing voltage transformers. M. K.

RADIO AND TELECOMMUNICATION SECTION

As Good as the Old Days

The establishment of a complete national v.h.f./f.m. sound broadcasting service is now under way, and the meeting on the 12th December 1956 provided a welcome opportunity for hearing some of the problems involved and the way in which they were being tackled. Three papers were presented: *The B.B.C. Sound Broadcasting Service on Very High Frequencies*, by E. W. Hayes and H. Page; *Frequency-Modulated V.H.F. Transmitter Technique*, by A. C. Beck, F. T. Norbury and J. L. Storr-Best; and *Frequency-Modulated Quartz Oscillators for Broadcasting Equipment*, by W. S. Mortley.

In introducing the first paper, Mr. Page gave a rapid account of the difficulties of medium-wave broadcasting which led to the desirability of setting up a national v.h.f. system. The decision to use frequency modulation had been taken as a result of full-scale field trials. The f.m. service is capable of giving excellent results, but certain precautions are necessary at a small percentage of receiving sites owing to the effect which can be produced by reflected signals, and a most interesting demonstration was given to show the nature of the resulting multi-path distortion. This distortion arises from spurious amplitude modulation of the received signal, and it can be minimized by effective limiting circuits in the receiver. Unfortunately a ratio detector used alone is not sufficiently effective in this respect; its extensive use in receivers is due to its contribution to a low overall cost.

Mr. Hayes dealt with questions of transmitter and service planning, and emphasized the necessity for efficient use of staff. The transmitters are co-sited with the television transmitters and are designed for remote operation during periods when no television signal is being radiated. The manufacture and erection of the f.m. aerials had raised interesting problems.

Mr. Beck explained the successful technique employed for combining the outputs of two similar transmitters in parallel by arranging for them to feed separate parts of the transmitting aerial, and the requirements of the necessary phasing controls between the transmitters. One of the modern 10 kW transmitters was then described in some detail, including the automatic phasing control for parallel operation and the technique whereby the centre frequency of the transmitter is controlled.

Mr. Mortley, in presenting the third paper, dealt with another method of frequency control for f.m. transmitters which relies upon direct frequency modulation of a quartz oscillator. This system has been in use at the Wrotham transmitters of the B.B.C.

Opening the discussion, Sir Noel Ashbridge gave a concise account of the history and background considerations in which frequency modulations had grown up. He mentioned the many conferences which had been convened over a number of years and the emphasis which television had enjoyed. The B.B.C. had adopted frequency modulation as the result of careful experiment, and it is interesting to record that in no country is there a v.h.f. system using amplitude modulation. Mr. B. N. MacLarty also paid tribute to the early experimental work carried out by the B.B.C. on modulation systems at a time when we were all subject to considerable publicity pressure from across the Atlantic on the merits of frequency modulation. He said that we had in this country made substantial contributions to the art, and he instanced the technique of paralleling transmitters and the direct frequency modulation of quartz oscillators.

Sir Harold Bishop quoted some interesting figures, from which it appeared that the Copenhagen plan had been drawn up for a number of European medium-wave transmitters which was little more than half the number of those currently in use. He considered that sound broadcasting was a most important service, and the expenditure necessary on a v.h.f. service was justifiable.

The meeting was pleased to hear that Capt. P. P. Eckersley was now able to get as good a quality as when he first started!

Other contributors to the discussion made useful points on frequency separation between stations, co-channel interference problems, and the merits of the ratio detector in receivers for dealing with impulsive interference. One of the

disappointments of the discussion was the fact that there seemed little in the way of spontaneous contribution, and the cause of this may well have been, as Sir Noel Ashbridge said, that each paper could itself have formed a subject for an evening meeting. Certainly the slowness in open discussion was not due to low numbers, since the papers had attracted a very large audience. A. J. B.

SUPPLY SECTION

Protecting the Supply Lines

Fog, or possibly the fear of it, and not lightning, was the main meteorological hazard of the Supply Section meeting held on the 19th December 1956, when Mr. A. Morris Thomas and Mr. D. F. Oakeshott presented their paper entitled *Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33 kV and Above*, a review of which appears on p. 95. The inclement weather reduced the attendance at the meeting to a small number, which was unfortunate in view of the importance of the paper.

Mr. Morris Thomas briefly summarized the paper—a difficult undertaking, since it was already a much shortened version of an E.R.A. Report. The discussion which followed was a lively one and the lack of members present did not result in a dearth of contributors.

Mr. N. G. Simpson, in opening the discussion, stressed the importance of the export market and emphasized that climatic conditions in the southern hemisphere were totally unlike those which were experienced in this country. The design of overhead lines required in tropical countries was largely determined by lightning conditions, whereas, in the northern hemisphere, ice loading was the factor of great importance. He further stressed that operational experience under lightning conditions is still extremely limited, and he strongly recommended that copies of the paper should be given wider circulation to members oversea in order to obtain as many comments from them as possible.

Mr. R. Davis in his vigorous and humorous style joined issue with the authors on some of the more detailed points in the paper, and three doctors—J. S. Forrest, R. H. Golde and C. H. W. Clark—further dissected the paper in order to discover whether it had any shortcomings of a serious nature. Despite certain minor ailments being diagnosed, the patient as a whole was declared healthy.

Mr. D. M. Cherry and Mr. R. A. York stressed the economical side of the subject, and both considered that the use of high-speed auto-reclosers could do a great deal to improve the lightning performance of lines so far as the continuity of supply to consumers was concerned.

In replying to the discussion, Mr. Oakeshott said that he had hoped that the long list of acknowledgments at the end of the paper to individuals and organizations, for the help he had received in its preparation, would shield him from the more awkward questions. Nevertheless, he was pleased that the paper had provoked the comments it had, and he suitably replied to the points which had been raised.

The Chairman, Mr. P. J. Ryle, proposed a vote of thanks to the authors and expressed his pleasure that the paper, which was the first of its type to be submitted by a member of the E.R.A., had been such a success, and he forecast that in the future it would become a source of reference for all engineers interested in the insulation and surge protection of overhead lines. R. A. Y.

UTILIZATION SECTION

New Induction Motors

At the meeting on the 15th November 1956 two particularly interesting papers were presented.

The first, by E. R. Laithwaite and P. J. Lawrenson, was *A Self-Oscillatory Induction Motor for Shuttle Propulsion*, which showed how an induction motor could be constructed so as to produce a magnetic field travelling in a straight line and thus used to propel a shuttle across a loom. The authors described a stator arrangement by which the shuttle could be made to oscillate without the use of switches, and they suggested that a workable system could be evolved, although it would involve considerable changes in loom design. Apparatus illustrating the principle employed was also demonstrated, and this created a considerable impression. A short review of the paper is given on p. 96.

The second paper, *Brushless Variable-Speed Induction Motors*, by F. C. Williams, E. R. Laithwaite and L. S. Piggott, described, in effect, the results of the further work they had carried out on this subject since the original paper which two of the authors read before the Section in December 1954.* It will be recalled that this earlier paper gave details of a new type of brushless variable-speed induction motor, which was based on the principle that when a piece of conducting material is placed in a moving magnetic field, it can be caused to move at a speed exceeding that of the field by constraining it to move at an angle to the direction of motion of the field. This principle was demonstrated by a disc type of machine, which, however, was so inefficient that no reasonable idea of its practicability could be formed. The present paper described a more efficient version of this machine which has a spherical barrel rotor, and experiments have demonstrated that a speed range of up to 5·5 : 1 can be obtained. The authors showed that the losses involved could not be accounted for by conventional theory, which had to be abandoned in any detailed analysis. A short review of their paper appears on p. 99.

The ensuing discussion was opened by Professor G. H. Rawcliffe, who considered that the authors of the second paper had given a superb example of a positive attack on the problem, in contrast to the negative attitude of many people of the 'It-can't-be-done' variety. He also felt that there should be a considerable application for this type of motor in the smaller sizes of machine, because many of these were at present sold with an efficiency much lower than the 44% which the authors had obtained.

As could be expected, many contributions to the discussion came from design engineers, one of whom openly confessed that squirrel-cage motors were not simple things to design. A second speaker said that the evening's demonstration of linear motion might be to industry what the jet engine had been to air transport, while another suggested that Yorkshire people would not regard with enthusiasm the use of an electromagnetic shuttle made in Manchester!

The authors' replies to the discussion were punctuated with many shafts of wit. Among these were such sallies as 'We made progress as soon as we became a little more fundamental'; 'We had taken the trouble to make the machine work before writing about it'; and ' "Costs" are what it cost to make, but "price" is what you can get for it'.

Altogether it was a most instructive and entertaining evening. R. H. R.

* See *Journal I.E.E.*, 1955, **1** (New Series), p. 94.

NEWS *from the Centres*

GLASGOW

SCOTTISH CENTRE

Single-Minded Diners

A record number of almost 300 members and guests, under the chairmanship of Professor F. M. Bruce, attended the Scottish Centre Dinner-Dance at the Grosvenor Restaurant, Glasgow, on the 20th November 1956. Professor Bruce, being yet a bachelor, was most ably and charmingly assisted by Mrs. de Villiers as hostess.

The speeches this year were light in texture and contained neither clarion calls to duty nor pronouncements of urgent national importance. Mr. James Stirrat, late Deacon Convener of the Trades of Glasgow and a bachelor, proposed the toast of The Institution and made amusing play with the fact that his namesake Mr. James Stirrat, member of the Scottish Centre Committee and also a bachelor, lived, by a strange coincidence, at an almost identical address. It appeared that considerable confusion resulted with regard to bills and other more personal items of correspondence. In replying to the toast, Sir Archibald Gill, Past-President, seemed to imply that he had been forced to emerge from his retirement and rejoin industry in order to avoid a full-time maintenance job on the electrical equipment at his home.

Dr. J. W. McFarlane, Chairman of the South-West Scotland Sub-Centre, proposed the toast of the guests, and, spurred on by the promise of a double whisky for every minute by which he fell short of his allotted time, made a rapid but nevertheless extremely amusing speech, with an apt remark for each of our official visitors. Mrs. B. R. Sprunt, Chairman of the Scottish Council of the Electrical Association for Women and a native of Berwick-upon-Tweed, replied, hoping that her invitation was not a preliminary move in an attempt by Scotland to annex that free and ancient borough.

The formal proceedings concluded with the usual toast of the Chairman, proposed by Mr. H. V. Henniker, Senior Vice-Chairman. Professor Bruce replied, referring particularly to the indefatigable efforts of Mr. J. H. P. de Villiers, Honorary Secretary, in organizing this and the numerous other activities of the Centre.

Enjoyable and energetic dancing brought to a close another most successful function.

E. O. T.

LEEDS AND HULL

NORTH MIDLAND CENTRE

Annual Dinner

At our Annual Dinner, which was held in Leeds on the 16th November 1956, with 236 members and guests present, the toast of 'The Institution' was proposed by the Lord Mayor of Leeds, Alderman T. A. Jessop, who paid tribute to the great benefits which mankind had reaped from the harnessing of mighty power by the electrical engineer.

The President, Sir Gordon Radley, whom we were honoured to have with us, said in reply that he took great pride in two outstanding achievements which came to fruition this year. First, the opening of Calder Hall nuclear power station, which was pumping 65 MW into the Grid, and which was a wonderful example of co-operation between civil, mechanical and electrical engineers, and, secondly, the opening of the transatlantic telephone cable, on which three nations had worked as a team—if only the nations of the world at large would pull together in this way! He next congratulated the Centre on its steady progress, and said we should all encourage young people to join our profession. The Institution's education policy is that specialists should be built only on a foundation of basic engineering knowledge, whereas in Russia, where large numbers are being produced, this does not usually apply; our method should produce more adaptable engineers.

Some personalities at the Annual Dinner of the North Midland Centre

Left to right: Mr. W. K. Brasher, Sir Gordon Radley, the Lord Bishop of Durham, Alderman T. A. Jessop (Lord Mayor of Leeds) and Mr. W. K. Fleming (Chairman of the Centre).

Our Chairman, Mr. W. K. Fleming, in proposing the toast to our guests, said how honoured we were by the presence of the Lord Mayor of Leeds, and he congratulated Sir Gordon on the award of the K.C.B. and jointly on the award of the Christopher Columbus Prize for his work on the transatlantic telephone cable. He also spoke of our pleasure in seeing Mr. W. K. Brasher, the representatives of the kindred Institutions, our own Mr. J. R. Rylands in his new role as President of The Institute of Fuel, and the three Chairmen of Local Centres of The Institution. Finally he coupled the toast with the name of the Rt. Rev. the Lord Bishop of Durham. The Bishop replied to the toast in a witty speech, which he concluded by saying we were at the dawn of a new age, and that the spirit and soul of the people were the responsibility not only of the Church but of all of us who are dealing to-day in mysteries too deep for the common man to penetrate. He hoped that God would bless our discoveries and give us grace to use them for the benefit of man. The formal dinner then closed, and members joined in a reunion.

DISTRICT MEETING AT HULL

The second District Meeting of the session was held on the 6th December 1956, when Mr. W. S. Milner, convener of the Hull District Meetings, gave an address entitled *Education*

in Electrical Engineering. This dealt most interestingly with the basic theoretical and practical training desirable for the three streams of workers in the electrical industry—craftsmen, technicians and technologists. Our interest was held throughout and we particularly liked the diagrams showing the various phases in the training courses. Mention also was made of the sandwich diploma apprenticeship and technician's courses. An interesting discussion was opened by Mr. A. Johnson, who was followed by six other speakers. The last, Mr. J. Byrnes, contrasted the financial aid given by Russia to her technical students with the meagre aid (when the various means tests have been applied) given to similar students here. Following the discussion, a vote of thanks to Mr. Milner was proposed by Mr. H. V. J. Harris, who had very ably acted as Chairman at this meeting.

J. L.

DISTRICT MEETING AT CATTERICK

First Meeting in a New District

At a special meeting of the North Midland Centre held at Catterick Camp on the 15th May 1956 it was unanimously agreed that the holding of District Meetings in Catterick was a desirable and practicable proposition, and Lt.-Col. R. G. Miller, R. Signals, agreed to act as convener. In consequence, an inaugural meeting was held in the Royal Signals Headquarters Mess, by permission of the Mess Managing Committee, on the 22nd November 1956.

After a buffet tea, some 115 members and visitors being present, the convener opened the meeting at 6.15 p.m. He began by thanking the senior members of the North Midland Centre—many of whom were present in spite of the icy state of the local roads—for their help and encouragement in inaugurating this new series of meetings. He particularly mentioned Mr. F. Barrell (Past-Chairman), Mr. W. K. Fleming (Chairman) and Mr. H. A. Carr (Honorary Secretary).

He announced that he had formed a small committee consisting of Lt.-Col. R. O. Girdlestone, R.E.M.E., Major D. T. W. Gibson, R. Signals, Major J. N. Hallett, R. Signals, and himself. They were planning the next meeting for the spring of 1957.

He then called on the speakers to read their papers, both of which had been specially prepared for the occasion. Dr. J. S. Saxton spoke on the theoretical background and present engineering position of ionospheric-scatter propagation, not hesitating to refer to the disadvantages as well as to the advantages of the method. He was followed by Mr. W. J. Bray, who read a corresponding paper on tropospheric scatter, ending with a mention of the system currently in operation in North America.

Brig. J. D. Haigh opened a most interesting informal discussion in which several members of the audience joined, military interest in the new techniques being very strong. One visitor was particularly intrigued by the system called 'Janet', which provides intermittent but very-high-speed communication by scatter from the trails of the larger ionospheric meteors; the speakers felt that this system had yet to prove itself conclusively. The discussion had to be closed for lack of further time, although it was evident that more people would have liked to contribute. In thanking the lecturers on behalf of the audience, Brig. Smijth-Windham considered that tropospheric-scatter propagation was a very promising technique from the Services' point of view. He was not so happy about ionospheric scatter.

After the meeting the speakers and a number of visiting members were entertained to supper in the Mess.

LIVERPOOL AND CHESTER

MERSEY AND NORTH WALES CENTRE

The first half of the session proved very successful with an interesting programme and active discussions at the four meetings in Liverpool and three in Chester. District meetings were well attended at Llandudno, Warrington and Wrexham; at each town Mr. P. d'E. Stowell was invited to repeat his Chairman's address, in which he reviewed *Some Aspects of Electricity Distribution*. Also at Wrexham Mr. G. P. Anderson presented his paper on *Modern Short-Circuiting Technique*.

Contacts have been maintained with other engineering societies; the President and members of the Liverpool Engineering Society attended the lecture by Mr. A. R. Cooper on his visit to Russia, members of the Centre being invited in return to hear a paper by Mr. N. Milne on *The Electronic Control of Machine Tools*.

The Annual Dinner-Dance will be held at Hulme Hall, Port Sunlight, at 7 p.m. on the 22nd March; tickets are obtainable from Mr. S. Towill, price £1 8s. 6d. each. The Golf Competition, which usually contributes well to the Benevolent Fund, has been fixed provisionally for the 28th May. Once again this will be held at Southport, through the hospitality of the Southport and Ainsdale Club. A Summer Visit has been arranged for Saturday 15th June, when members and ladies will be able to visit Calder Hall.

The Centre suffered a severe loss by the sudden death on the 5th January of Mr. E. J. Evans, Senior Vice-Chairman.

E. W. A.

SHEFFIELD AND SCUNTHORPE

SHEFFIELD SUB-CENTRE

Fast Output

The session was opened on the 17th October 1956, when Mr. G. G. Nicholson was introduced as the new Chairman by Mr. F. L. Parkins, in the unavoidable absence of the outgoing Chairman, Mr. W. Rewcastle.

Mr. Nicholson gave his address entitled *Electrical Developments in the Production of Sheet Steel*, which was of particular interest to the many industrial members present, being centred mainly on a description of the electrical plant and control gear associated with large steel-works rolling-mill plant.

The lecture was illustrated by slides and an excellent short colour film showing one of the largest and latest five-stand high-speed strip mills producing 38 inch $\times$ 0·01 inch steel plate at sixty miles per hour from the final rolls. This particular mill was equipped with one 1 750 h.p. motor, three 3 500 h.p. motors and one 4 500 h.p. motor for the stand drives, and one 800 h.p. motor for the reel—an impressive total of 17 550 h.p.

The Power of Scotland

Following the precedent of the last few years, the second meeting of the session was held at Scunthorpe on the 7th November 1956, at the New Technical College, for which our thanks are again due to the Scunthorpe Education Committee.

Mr. L. H. Dickerson's entertaining presentation of the late Mr. Lawrie's paper on *Highland Water Power—The Development of the North of Scotland Hydro-Electric Board* lost none

of its interest through being delivered in the plains of Lincolnshire; indeed the coloured slides roused nostalgic memories in many who had had previous associations with a more uneven countryside.

The discussion, opened by Mr. M. P. Rathbone, ranged widely over the steps taken to preserve the fish life, including electronic counters to record the numbers passing through the fish ladders; the problems of providing amenities for staff in out-of-the-way places; transport difficulties in moving heavy equipment; erosion of turbine blades caused by cavitation; the economics of hydro-electric power in comparison with steam stations; and the prospects of base-load nuclear power stations in combination with pumped-storage schemes to deal with peak loads, which Mr. Dickerson, in his reply, thought a promising future development.

Holes and Their Uses

At the meeting in Sheffield on the 21st November the immediate Past-Chairman was presented with a copy of *The History of The Institution* signed by the President and Secretary of The Institution, and by the Chairman of the North Midland Centre. Mr. F. L. Parkin proposed a vote of thanks to Mr. Rewcastle for his services during his term of office.

The Chairman formally welcomed a new Corporate Member, Mr. J. W. Ibbotson, of Doncaster, and presented the Graduate and Student Premium to Mr. C. F. R. Bradshaw for his paper *Arc Furnaces*.

Mr. T. H. Kinman then read the paper *Germanium and Silicon Power Rectifiers*, of which he is one of the joint authors. The subject had attracted a large audience in view of the interest in the prospects of these semi-conductors for power conversion after their recent rapid development in the electronic field.

The conception of holes and their movement, put forward in the explanation of the *p–n* junction theory, was received with some reserve, and the discussion, which lasted for nearly an hour, was sustained mainly by members from the teaching profession and industry—members from the supply side, though well represented, being unusually reticent.

Industry was mainly interested in when this new device is likely to be available, and whether it will be suitable for the arduous conditions of temperature and vibration on large cranes and similar possible applications. Although development at present appears to have been concentrated more on the germanium rectifier, Mr. Kinman thought the silicon junction may offer better prospects for difficult conditions.

He concluded with an interesting reflection that semi-conductors may yet provide a direct link between nuclear fission and the production of electrical power.

Mr. G. L. Mason has been appointed Honorary Assistant Secretary following Mr. G. H. Byrom's resignation from this position on leaving the district. L. F. S.

STOKE, STONE AND STAFFORD

NORTH STAFFORDSHIRE SUB-CENTRE

At the Stoke meeting on the 26th October 1956, the Chairman, Dr. E. R. Patrick, formally welcomed Mr. P. W. R. Gatliff, Mr. D. V. J. Leitch and Mr. R. H. Stewart as Corporate Members. He then introduced Mr. E. L. E. Wheatcroft and Mr. H. H. C. Barton, and called on the former to present their paper on *The Potentialities of Railway Electrification at the Standard Frequency*.

Among guests invited to attend this meeting were members of the railway staffs of Crewe and Manchester, and Mr. K. Taylor opened the discussion, followed by Mr. T. E. Calverley and many other members and guests. The widely different points of view added much to the interest of the discussion of this subject, particularly as a 50-c/s system has been adopted, since the paper was written, as the standard for main-line electrification in Britain.

The authors dealt very ably with the various points raised in the discussion, and Mr. P. Finch, in moving a vote of thanks to them, said how much this instructive paper had been enjoyed.

Soirée Électromusicale

The subject of the meeting at Stone on the 19th November led members into what, for many of them, must have been a completely new field, when Mr. A. Douglas delivered his lecture on *The Generation and Synthesis of Music by Electrical Means*. Mr. Douglas discussed the attributes of a musical tone and described electronic methods of producing tones of different qualities. The capabilities of commercial instruments of this type developed in various parts of the world were then described and illustrated by recordings which showed that the sounds produced by most orchestral instruments, including the organ, could be more or less faithfully reproduced. He also indicated how this equipment could be used to remedy the deficiencies in harmonics which occurred at some part of the range of many orchestral instruments.

Mr. Douglas kindly agreed to answer questions, and the ensuing discussion, opened by Mr. G. Reddyhoff, revealed unsuspected depths of musical knowledge in many members. Questions were raised on whether players would agree that the harmonic structure should be the same throughout the range of an instrument, and on whether the great composers of to-day were following up the new form.

The author replied that no composer in this country has yet tolerated the new instrument, let alone written for it, although some German composers are concentrating on the possibilities now made available to them, and developments are also taking place in America.

Mr. C. C. Pimble, in proposing a vote of thanks for this fascinating lecture, said he had in the past produced many tones which he was sure could have been improved by synthesizing, but he was pleased to know that they could not yet 'mess about' with the violin. The author had shown an exceptional knowledge of all kinds of organ, and he was to be heartily congratulated on the way he had dealt with the many questions fired at him from all angles.

Full House

The Annual Dance on the 23rd November, held at the Crown Hotel, Stone, again proved to be a most enjoyable social function. Tickets to the capacity of the room had been sold several days before the event, and the record number of 156 members and guests attended. The increased attendance and much of the success must be attributed to the efforts of the Graduate and Student Section made in response to an invitation to take a closer interest in the organization. It was pleasing to note the much larger proportion of Graduates and Students present on this occasion. To encourage their further interest, the organization of next year's dance will be left largely in the hands of the Graduate and Student Section.

The prizes were gracefully presented by the Chairman's daughter, Mrs. H. S. Brown, and the Chairman, Mr. A. T.

Chadwick, warmly thanked Mr. W. E. Darby for the lively way in which he had carried out the duties of Master of Ceremonies, and all others who had contributed to a most successful evening. L. G.

More Chairs for the Modern Steel-Works

The new Chairman of the Sub-Centre, Mr. A. T. Chadwick, took the chair for the first time at the meeting at Stafford on the 11th December 1956, and thanked Dr. E. R. Patrick for extending the normal period of office to bridge the gap caused by his absence. He welcomed Mr. A. B. Dow as a Corporate Member.

The speaker for the evening was Mr. H. S. Brown, who gave a lecture on the design of modern rolling mills. With the aid of a film and slides, a most informative survey was provided of the problems in this field. It became evident that continuity of operation is the main preoccupation in steel-works, and that some, at least, of the complex electrical equipment employed nowadays is necessary to protect the operators from the worst excesses of their own enthusiasm. The modern emphasis on simplicity in both operation and maintenance was well brought out in the lecture; the idea that greater ease makes for greater efficiency has been carried to lengths where 'to sit down on the job' has become quite respectable.

The lecturer mentioned the action of 'loopers' in handling awkward twisting of material, and Dr. Patrick demonstrated the principle in assisting Mr. Brown with a blackboard. The subjects of peak demands and energy costs were covered, and they provoked some comments in the discussion from representatives of the supply industry, to whom, it appeared, the expression 'blooming mill' could have more than one meaning.

The discussion was opened by Mr. T. E. Calverley, and a vote of thanks proposed by Mr. P. D. Gilbey was carried with acclamation by the eighty-one members present. D. H. T.

OXFORD

DISTRICT MEETING

On the 9th January 1957, fifty members and friends, under the chairmanship of Mr. V. Brice, gathered at the Oxford office of the Southern Electricity Board to hear Mr. R. A. L. Cole give an informal talk on *The Elementary Physics of Transistors*. Mr. Cole described the atomic structure of semi-conductors and explained how control of conductivity can be achieved by the introduction of other elements. He then dealt with the physics of junction rectifiers and transistors and gave examples of simple uses and circuits. Great interest was shown in the exhibits which Mr. Cole ably demonstrated.

Mr. D. E. Westwood, in his vote of thanks, complimented the lecturer on the simplicity with which he had explained a complex subject. E. H.

NEWS *from Abroad*

The Duke of Edinburgh in the 132 kV switching station attached to Guthega power station.

With the Duke is Mr. J. C. Callinan, Chief Electrical and Mechanical Engineer, and behind, at the left, is Mr. T. A. Lang, Associate Commissioner, Snowy Mountains Hydro-Electric Authority.

AUSTRALIA

NEW SOUTH WALES OVERSEA COMMITTEE

Royal Tour of the Snowy Mountains

During the three days 26th–28th November 1956, H.R.H. the Duke of Edinburgh made a 275-mile tour of the Snowy Mountains hydro-electric scheme.* The Duke was accompanied by Senator W. H. Spooner, the Minister for National Development, and Sir William Hudson, Commissioner of the Snowy Mountains Hydro-Electric Authority.

The tour commenced with an inspection of the Scientific Services Laboratories of the Authority at Cooma, where the Commissioner explained the outlines of the scheme with the aid of a three-dimensional model. The Royal party were then shown a film made by the Authority's own film unit entitled *Where the Hills are Twice as Steep*, of which a copy was later presented to the Duke. Demonstrations were arranged of photo-elasticity and spectrography and of hydraulic model studies and soil conservation.

After lunch the party proceeded 65 miles to see the Guthega project in operation near Mount Kosciusko. The 60 MW power station, which was on continuous full load as a result of recent melting of the snow, was explained to the Duke; he expressed a very keen interest in the plant and displayed by his many questions the considerable knowledge which he has of such power-generation projects. In the 132 kV switching

* An article on the Snowy Mountains Scheme, with a sketch map of the district, was published in the *Journal*, March 1956, p. 157.

station, he was particularly impressed by the measures necessary in the mountains to guard against lightning strokes.

The first night was spent at the construction township of Island Bend on the Snowy River, and next day the party visited in turn the works now in progress on the earth dam at Adaminaby, the 14-mile diversion tunnel which will carry the water from Adaminaby reservoir westward under the Dividing Range, and the concrete arch dam at Tumut Pond at the end of the diversion tunnel. At Junction Shaft, which lies along the route of the tunnel, the Duke descended 300 ft down the shaft and visited both the upstream and downstream tunnelling faces by means of the electric traction system. At Tumut Pond he operated the recently completed cableway to send off the first bucket of concrete for the dam.

After spending the night at Cabramurra, the Authority's township high in the mountains, the party visited the excavation now in progress for the Tl underground power station, which will have four 80 MW generators. At Cabramurra, the Resident Electrical and Mechanical Engineer, Mr. C. Dale, was presented to His Royal Highness, and he demonstrated the plant in the Authority's Diesel power station.

The Royal party proceeded to a picnic lunch by the Eucumbene River, near a former construction camp for the Authority's transmission lines, and thence to the Cooma airport.

Throughout the tour, the Duke expressed great interest in, and appreciation of, all the works of this huge scheme.

A. C. H. F.

Past-President at Sydney

On the 27th November, at the University Club at Sydney, the New South Wales Oversea Committee held a social function at which members were given the opportunity of meeting Sir Harold Bishop, Past-President, who was visiting Australia in connection with the Commonwealth Broadcasting Conference. Later the same evening, Sir Harold addressed a joint meeting of our Institution and The Institution of Engineers, Australia, at the Maritime Service Board Assembly Hall, Sydney.

J. T. R.

NIGERIA

WEST AFRICAN JOINT OVERSEA GROUP

New Locomotives

At the kind invitation of the Nigerian Ports Authority, thirty-five members and guests visited the new wharf at Apapa, Lagos, on the 2nd November 1956, to inspect two of the new Diesel shunting locomotives recently commissioned there. The locomotives were exhibited with covers removed, and, in a demonstration train alongside, spare parts, special tools and arrangement drawings were on display. Lantern slides were shown depicting assembly, maintenance and operation of the locomotives. The locomotives are of the 0–6–0 rigid-frame type, powered by 400 b.h.p. 6-cylinder 750 r.p.m. Diesel engines. Transmission was through a Voith torque converter and two hydraulic couplings and mechanical gearing. The total weight of each locomotive was just under 39 tons. At the conclusion of the visit the Group were kindly entertained with refreshments in the Atlantic Terminal at Apapa. The arrangements for the visit were made by Col. D. H. May.

Two Full Days

A two-day meeting was held in Ibadan on the 23rd and 24th November 1956, attended by some twenty members from Lagos and fifteen from Ibadan.

On the first morning the Group visited the Lafia canning factory by kind invitation of the Western Region Production Development Board. The Group saw the weighing, storing, grading and washing of citrus fruits, and the processes for the production of canned pineapples, citrus juices and citrus segments. The tin reforming plant, water treatment and boiler plant, and standby Diesel generating plant were also inspected. The Group were conducted round the works by the manager, Mr. V. Trinder.

After lunch, part of the Group visited the works of the Nigerian Tobacco Co., while the remainder visited the new waterworks of the Ibadan District Council. Here, conducted by Mr. T. A. MacLachlan, Chief Water Engineer, Western Nigeria, they saw the reservoir and dam, where three to four years' supply is impounded from a catchment area of 120 sq. miles. The water is treated in a purification and filtration plant and put into supply through pumps with a daily capacity of 2¼ million gal. The Group examined a new treatment and pumping plant of similar capacity in an advanced stage of construction.

The Group then visited the Eleiyele power station of the Electricity Corporation of Nigeria, where they were shown round by Mr. K. Widgery, Engineer and Manager. They saw a mixed Diesel and steam installation of 5 200 kW installed capacity. They also saw, in the early stages of construction, a new Diesel station of about 6 000 kW installed capacity.

On the 24th November the Group were shown round the Ibadan University College Teaching Hospital by the Consulting Architect, Mr. A. Gray and the Resident Architect (Federal Public Works Department), Mr. W. S. A. Prew. The Group made a complete tour of this 510-bed hospital, which is one of the major current civil engineering works in Nigeria. Later the Group were entertained at a cocktail party by Mr. J. R. Bull and Mr. Head.

Conversazione at Ikoyi, Lagos

At a Conversazione held on the 27th November, 110 members and guests met the Chairman, Mr. R. Bridgman, and Mrs. Bridgman, and, after cocktails and supper, were entertained by a film show.

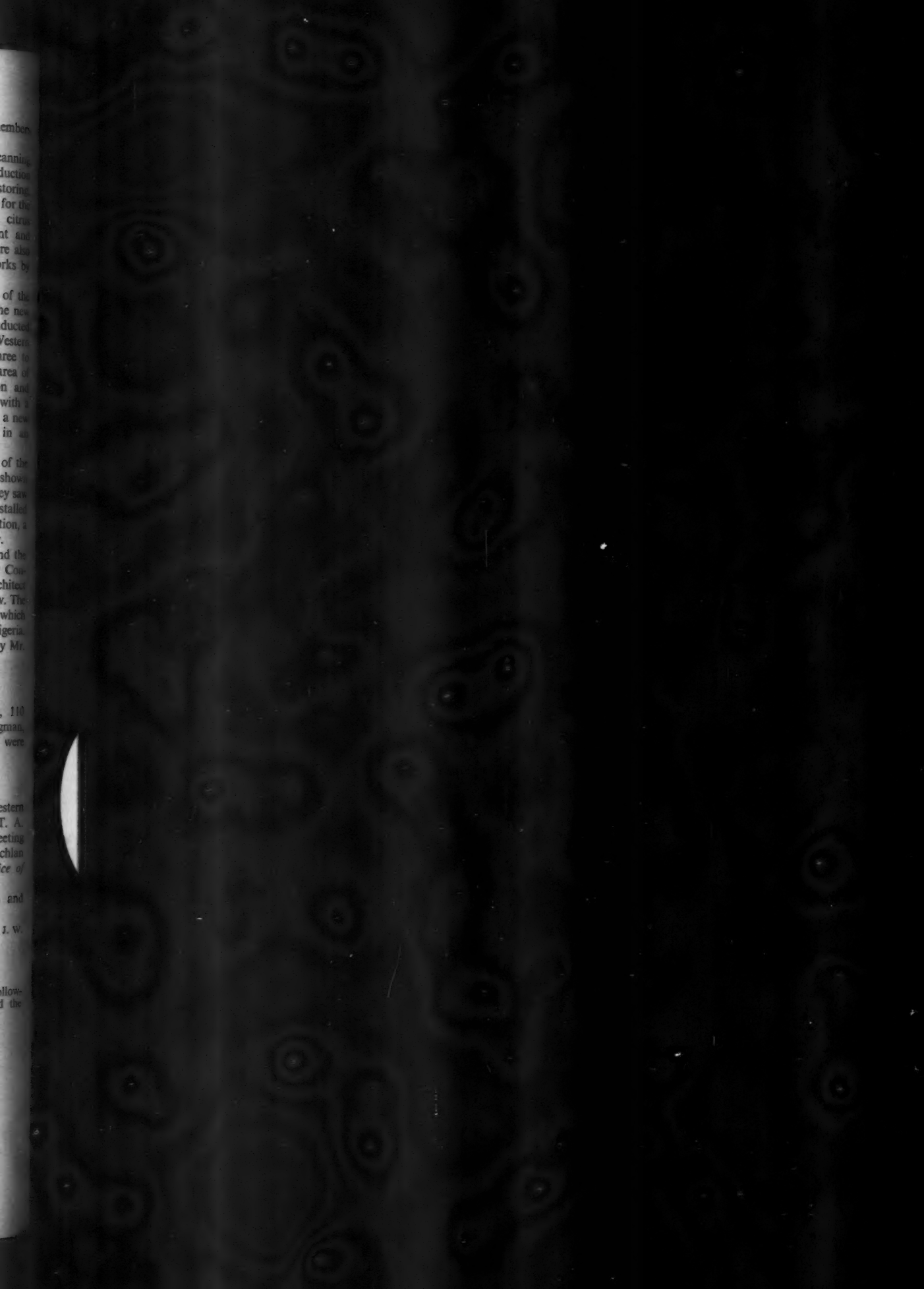
A New Branch at Ibadan

A branch of the Group has now been formed in Western Nigeria, centred on the town of Ibadan, with Mr. T. A. MacLachlan, M.I.C.E., as Chairman. At an Ordinary Meeting at Lagos on the 29th November 1956, Mr. MacLachlan presented his paper entitled *The Problems and Practice of Water Supplies in Western Nigeria.*

The meeting was attended by forty-five members and guests, and refreshments were served afterwards.

R. E. J. W.

OVERSEA ATTENDANCE REGISTER

During the period 1st December to 31st December 1956 the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

COLLIE, G. B. (Christchurch, New Zealand)
HARVEY, H. G. (Nairobi)
HUDSON, J. T., B.E. (Wellington, New Zealand)
HUNT, R. E. (Tripoli)
MACLEAN, MAJOR H. J. C. (Dar-es-Salaam)
SMITH, D. H., B.SC.(ENG.) (Lagos)
STALLABRASS, J. R., B.SC.(ENG.) (Ottawa)
SUTHERLAND, D. G., B.SC. (Pietermaritzburg, South Africa)
WIDGERY, K. H., B.SC.(ENG.) (Lagos)